Enabling Eating in Virtual Reality

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Abstract

Over the past couple of years, the use of VR in different fields such as entertainment, education and training has dramatically increased. However, little is known on how we can use VR around food and our eating experiences which can affect our health and well-being. Thus, the focus of this thesis is to explore the applicability of eating in VR. Wearing a head-mounted display (HMD) while trying to eat virtual food and real food simultaneously is a challenging task. To address these issues, two user studies were conducted – a feasibility and a usability study.

Eating is a multi-sensory experience, but what makes it different from any human activity is how reliant it is on the chemical senses, particularly the olfactory sense for flavor perception. Knowing this, it is important to investigate the effects of olfactory cues and as well as food interaction in VR. Hence, the feasibility study explored the effect of the addition of olfactory cues to food exposure in VR in the development of food cravings. Methods of this study was adapted from VR Cue-Exposure Therapies. Our results show that olfactory cues, paired with visual cues, can further increase food cravings. Meanwhile, the combination of visual, olfactory and interaction cues did not.

The usability study explored the possibility of eating in the virtual and real world simultaneously. Mechanically, the two primary ways in which we eat are either using our hands or using utensils. The experiment was designed with these two food interactions (one using bare hands and one using utensils) coupled with two levels of hand fidelity (high and low). Participants were asked to eat marshmallows using our VR setup and usability and the sense of presence were measured. The results showed that high-fidelity, bare-handed food interactions performed best compared to its low-fidelity counterpart and to food interactions using a utensil. This study concluded that such interaction may have performed well due to the type of food being eaten. In addition, the eating utensils we used for real-world dining may not necessarily be applicable in VR. Thus, designing future food interfaces for VR should consider these points.

Inevitably, eating and food interaction in VR is still underexplored territory and further research is needed to improve utility and applications related to food and eating.

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Please detail the nature and extent (%) of contribution by the candidate:

The user study was designed with the help of Simon Hoermann and Rob Lindeman. Simon mainly contributed on experiment design and data analysis. Rob Lindeman provided supervisory support and made sure the user study was and its design were ready before I executed the experiment. Also, he presented the poster during the conference. Carl Petersen mainly provided support on the research background/literature. All co-authors contributed at most 8% with the writing/editing/proofreading of the poster.

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Preface

Having a background in Information Technology (IT), I have always been fascinated with exploring and learning new technologies. Not only that, I was very interested in healthy eating, cooking and exercise. This interest came about a few years ago when I was overweight and was finding my comfort and stress relief in food. However, I found my solution in countering that in playing video games – specifically exergames. With this approach, I have managed to learn so many things about how our body works and how we can change the way we eat but most importantly, I have managed to lose 10 kg of weight playing these games. Hence, this is one of the reasons I have undertaken this research.

I wanted to explore the possibilities in the consumption of food/eating food in VR and its possible use in changing eating habits. During this journey, I have learned a lot of interesting details about eating – an activity that seems so simple is actually much more sophisticated and complicated. It is a fascinating topic yet very challenging. One of my biggest challenges is the fact that this study is hugely multidisciplinary. The multitude of different perspectives in eating in different fields made extracting relevant information an exacting process. Nonetheless, it was amusing to mull over so many different aspects of food and eating.

I hope this thesis will be useful to readers and researchers who are interested in the field of Human-Food Interaction as well as individuals who are passionate about the creation of new eating experiences. This thesis will discuss how I approached my research questions and the insights I have learned or gained from my results. Hopefully, this will help and contribute to the foundation of eating in virtual worlds and the possibility of creating shared eating experiences in the future. For me, there is no better way to connect people together than through food.

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List of Abbreviations

AB	Articulated hands, bare-hand interaction
ADL	Activity of Daily Living
AR	Augmented Reality
AU	Articulated hands, utensil interaction
CBT	Cognitive Behavioral Therapy
CET	Cue-Exposure Therapy
ED	Eating Disorder
FCQ-S	Food Craving Questionnaire-State
GAN	Generative Adversarial Nets
GP	General Presence
HFI	Human-Food Interaction
HMD	Head-Mounted Display
HTC	High Tech Computer (company)
INV	Involvement
IPQ	Igroup Presence Questionnaire
MR	Mixed-Reality
NB	Neutral baseline
PHC	Photo cookies
RC	Real cookies
RL	Realism
SB	Static hands, bare-hand interaction
SP	Spatial Presence
SU	Static hands, utensil interaction
SUS	System Usability Scale
UC	Urge to eat cookies
UE4	Unreal Engine 4
VC	Virtual cookies
VCI	Virtual cookies with interaction
VCO	Virtual cookies with chocolate scent
VCOI	Virtual cookies with chocolate scent and interaction
VR	Virtual Reality

1 Introduction

This thesis examines the feasibility and applicability of eating in Virtual Reality (VR) by using current technologies and knowledge in the field. When "eating in VR" is mentioned in this thesis, it does not just mean eating virtual food in the virtual world – it includes real food with its virtual counterpart in the virtual world.

1.1 Motivation

The initial motivating factor for this research has always been to explore how we can use VR for healthy eating and thus, support behavioral changes in eating habits by manipulating sensory cues. This could allow us to support people changing their eating habits, support treatments for people who have phobias related to food or just provide eating experiences to people who cannot usually enjoy them.

However, realization soon came that we do not have the technology yet to effectively do this. There are interface design challenges that are yet to be resolved and probably ethical issues that we may encounter in this domain – the relevantly small and young field of Human-Food Interaction (HFI) (Comber et al., 2014). In addition, there are no clear standard measurements, as of yet, that we could use in this field to validate user studies. Moreover, the VR community has just scratched the surface with regards to understanding our chemical sensory system due to its nature which is especially true for the olfactory system. Researchers have not yet figured out the mechanism (National Science Foundation, 2015) of how our olfactory system discriminates between thousands or even trillions of different odors (Goldstein & Brockmole, 2016a). It is possible that unlocking this mystery may make it plausible for us technologists to digitalize odor.

1.2 Research Approach

The aim of this research is to explore how we can incorporate eating into VR. To be able to do this, we need to first look at what defines and constitutes eating. Secondly, we need to explore our behavior around food. Thirdly, we need to understand how we experience flavor. Contrary to popular belief, most of what we call flavor comes from the olfactory system rather than our gustatory system, hence the emphasis on olfactory cues in this research. Lastly, we look at the current state of knowledge in HFI. These are all discussed in Chapter 2. From these points, this research aims to answer the following general questions:

- Would we even want to eat in VR?
- Would eating in VR give us a similar (or at least near) experience to reality?
- How easy is it to eat real and virtual food at the same time?
- Do we have the technology and equipment to do this?
- Are there any ethical and safety concerns that we need to consider?

To answer these research questions, two user studies were designed (Chapters 3 and 4). To give an overview, the first user study explored the use of sensory cues in the development of food cravings. The second user study explored food interactions with current VR technology. Lastly, Chapter 5 presents the conclusions of this research and suggests future studies in this field.

1.3 Contribution

Although eating in VR is a small growing domain, it has quite a broad scope due to the fact that eating is embedded into every part of our lives. It is also a multisensory experience that requires several sensory systems that we have. As such, research in this domain can be viewed in different lenses that can lead to different results. There is no definite consensus how one should research eating in VR although academics in this field have already started working on this and provide design criteria and/or guidelines. This thesis hoped to have done the same.

The findings of the first user study demonstrated that it is possible to have similar reactions or cravings to virtual food just like in the real world. It also points out that the addition of olfactory cues, which is very important in our perception of flavor, can increase these cravings. This reminds us that eating is a multisensory experience and it has to be studied in a multimodal approach. This study led to the idea of exploring food or eating interactions in VR. Research on food interactions in VR are few but growing. Previous attempts used at least two people for feeding in VR to work (Arnold, 2017). This research has attempted a similar scenario where the actual person immersed in VR can feed themselves although the visual food cue was still controlled by another person. In addition to that, this study has examined how we can integrate the common ways we interact with food (i.e., bare hands, utensil) from the real world into the virtual world. Results suggest that the appropriate interaction may depend on the type of food being served. Based on these experiences, this thesis raised several questions and considerations that may need to be addressed to move forward with this research.

2 Background

This chapter discusses previous work that has already been undertaken on eating. One of the challenges of doing research in this area is the fact that eating can be found in so many disciplines such as food science, anthropology, psychology, neuroscience, marketing, etc. However, this also presents enormous opportunities to explore the use of immersive technologies in these various disciplines. This research focuses on what makes us eat what we eat, the way we eat, how we behave around food, experiences related to eating and some of the attempts that were conducted to develop new eating experiences using Mixed Reality (MR) technologies.

To address these points and to show a background of this research study, this chapter is divided into two main sections:

- The Consumption of Food
- Mixed Reality Technologies in Food and Eating

2.1 The Consumption of Food

Eating is an activity we do to survive - to consume food through our mouth ("Eat," n.d.). Hence, the reason it is considered an activity of daily living (ADL) (Katz et al., 1970). In order to explore eating in VR, we first need to understand what eating is and the patterns associated with it.

The eating experience is largely influenced by our perception of flavor. Neuroscience explains that flavor is created in the brain where the different sensory systems (e.g., visual, auditory, somatosensory, trigeminal) contribute to it with emphasis on the chemical senses - gustatory and olfactory systems (Shepherd, 2006, 2013). In psychology, flavor is an experience created through the stimulation of different sensory modalities. Each sensory modality has its own contribution to the perception of flavor, as opposed to primarily attributing it to the olfactory sense (Spence, 2017).

However, eating is an experience that is even more sophisticated and multifaceted. . This is evident in the field of anthropology. In a review by Mintz and Du Bois (2002), they examined several food ethnographies or practices that discussed how eating patterns have been influenced by cultural identities, moral identities, societal and technological shifts and socio-economic changes.

2.1.1 Eating Behaviors and the Senses

Why do we eat what we eat? People's food preferences are influenced by certain factors such as culture, nutritional value, costs or even just for pleasure. Due to technological advancement and globalization, many people can now enjoy cuisines from around the world and have a lot of food options to choose from. This has created a multitude of challenges and research opportunities for the food industry. Hundreds of papers and articles were published on consumer food choices and behaviors alone in the past two decades (see examples in the succeeding sub-sections). Although, what is lacking in the literature is in-depth research on multi-sensory stimuli or cues. Food choices, preferences and behavior are influenced, not only by our hunger hormones – ghrelin and leptin (Klok et al., 2007), but more importantly, by *what we perceive through our senses* (Spence, 2017). We are going to look at examples of this in the following sub-sections.

2.1.1.1 Visual Cues

The food color, presentation of a dish on a plate, the cutlery used and even the packaging influences the appeal, our behavior, how satiated we may expect to feel and even our perception of flavor toward a given food (Spence, 2015; Wadhera & Capaldi-Phillips, 2014). Hence, the popular adage "You eat with your eyes" (Delwiche, 2012; Hurling & Shepherd, 2003). We use our eyes to get impressions and set expectations of a food product.

Color has a large role in defining our impression, expectations and liking of a food product (Spence, 2019b), or even flavor perception (Spence, 2019a). According to the psychology of colors, food with warm colors such as red, orange and yellow are more attractive than cool colors such blue, green and purple (Birren, 2016; Lee et al., 2013). Studies showed that certain color combinations can imply a certain taste quality. One study suggested that color can evoke food memory which can then influence taste expectations. Pink and purple were thought to evoke sweetness while green and yellow might induce a sour taste. White is thought to be salty while black is bitter (Woods & Spence, 2016). In addition to that, it would also seem that the context (i.e., foreground-background vs. side-by-side) on how the combination of colors are presented have an effect on taste as well (Woods et al., 2016; Woods & Spence, 2016). Packaging and brand labels can also suggest nutritional or health value of food products (see Chandon & Wansink, 2012 and Spence & Velasco, 2018 for reviews). For instance, paler or lighter colors can be used to imply a product's healthiness (Mai et al., 2016), although this should be viewed with caution, due to contradicting color-taste associations that may occur (Tijssen et al., 2017). On the other hand, the location of the images on food packaging can imply the product's flavor intensity. Images located on the bottom section of the packaging were thought to have more intense flavor than the ones whose images were on the top section (Togawa et al., 2019).

Tableware and cutlery also affect our satiation and food liking. For example, the contrast between the color of the plate and the food is an important factor to consider when plating food as it can suggest the flavor intensity of the food (Piqueras-Fiszman et al., 2012). Similar results were also seen in a study by Harrar and Spence (2013). Interestingly, their study also showed that the contrast between the color of the spoon and yogurt affected the yogurt's perceived taste. Sampled yogurt using white spoons were perceived as sweeter than when sampled with black spoons. Although, one study also suggested that dessert plated in a square black plate was preferred over one plated in a round white plate (Michel et al., 2015). Plating not only affect food liking but may also affect expected satiation. People tend to proportion food serving sizes depending on the size of their plates. One may experience satiation when food is served on a much smaller plate while another may experience less satiation when the same amount of food is served on a larger plate (Van Ittersum & Wansink, 2012). Similar results were also found for plates with different rim widths (McClain et al., 2013). They call this the *Delboeuf optical illusion* (Delboeuf, 1865).

2.1.1.2 Auditory Cues

Sound has also been shown to affect our eating behaviors, food preferences and flavor perception. For example, a field study demonstrated how ambient music in a retail setting can influence consumer purchasing patterns (Biswas et al., 2019). The results of this study showed that consumers are likely to buy healthier foods when low-volume music is playing on the background. Other results show that even ethnic music may influence consumers' food choices by selecting the same food from the same culture (North et al., 1999, 2016; D. Zellner et al., 2017). With regards to flavor perception, Spence demonstrated how the crackly noises of potato chips may affect our perception of their freshness (Zampini & Spence, 2004). He also reviewed how background noises or loud music can affect our ability to enjoy salty, sour and sweet tastes

(Spence, 2014). One study, for example, reported participants liking the sweet solution better while listening to loud music (Ferber & Cabanac, 1987). The type of background music was also reported to influence perceived pleasantness of certain foods. In a study by Ziv (2018), participants rated the cookies better with pleasant background music on than the cookies with an unpleasant music.

2.1.1.3 Chemical Senses – Gustatory and Olfactory cues

The gustatory and olfactory systems (known together as the *chemical senses*), are where we primarily experience flavor. These two systems are akin to each other. This can be seen in an area of the brain, called the piriform cortex (Maier et al., 2015), although some argue that flavor is an experience contributed to by all the primary senses (Shepherd, 2013; Spence, 2017). Nonetheless, these two systems have a large role in our eating experience (Boesveldt & de Graaf, 2017).

In the gustatory system we experience five taste qualities - sweet, sour, bitter, salty and umami (Goldstein & Brockmole, 2016b). Some scientists suggest a sixth taste quality which is fat (Besnard et al., 2016), while others say it is *kokumi* which is arguably more of a "feeling" than a taste itself (Feng et al., 2016). Contrary to what we used to believe about the tongue map (Hänig, 1901), taste buds in our tongue have the ability to perceive each of these qualities. What is more interesting is that some studies have also observed that we attribute most taste qualities to certain foods' (raw and moderately processed) nutritional value. For example, savory foods are more likely to be expected to have high protein content (van Dongen et al., 2012) while sweet foods can mean high-energy value or high in carbohydrates (Beauchamp, 2016). Although this may be the case, another study suggests that our eating behavior may also be affected by our taste sensitivity. Higher taste sensitivity might mean higher avoidance of certain bitter or sour foods (Puputti et al., 2019). This might also correlate with some people who seem picky with their food. They may be "supertasters". These are people who just happen to taste at a higher degree (Bartoshuk, 1991). This leads some of them to avoid certain foods or eventually develop selective eating disorder or avoidant restrictive food intake disorder (Golding et al., 2009).

In the olfactory system, there are two types of ways in which we process odors – orthonasal and retronasal olfaction. Retronasal olfaction is where flavor sensation mainly occurs while orthonasal olfaction occurs when we sniff (Rozin, 1982). Just like visual food cues, the orthonasal olfaction cues can give us impressions or expectations from food and these two may have a cross-modal interaction, especially when they correspond to each other (Zellner, 2013). For example, a study by Morrot et al. (2001) showed that some of their wine panelists mistook white wine as red wine when dyed with red food coloring. However, this seems to only work when the visual cues modulate orthonasal olfactory cues and not the other way around (Tamura et al., 2018), and does not seem to be the case for retronasal olfaction (Koza et al., 2005).

With regards to behavior, ambient scent was seen to have a reversal effect in our food preferences. The longer the exposure to a certain food-related scent, the lesser the preference for that certain food. For example, having been exposed to a cookie scent for a considerable amount of time will lessen the likelihood of a person to purchase cookies (Havermans et al., 2009; Biswas et al., 2014; Biswas & Szocs, 2019). These studies suggest that olfactory cues can be used to enhance or diminish food and eating-related behaviors.

2.1.2 Eating Behaviors and Disorders

Researching our eating habits and how we behave around food is not only a fascinating but an important endeavor since it has a direct impact on our health and well-being. One of the ways to be healthy is to eat healthily. What does healthy eating mean? What is healthy food? Unfortunately, there is no straight answer to this question. Popular opinion is very varied and subjective (Bisogni et al., 2012). Some say eating a low-calorie diet or setting up calorie restrictions on your diet is the way to a higher quality of life (Martin et al., 2016). Others say going vegan (Fox & Ward, 2008) or just eating more fruits and vegetables is the way or as long as the product is organic (Paisley & Skrzypczyk, 2005). Others believe cutting out a certain macronutrient in one's diet such as fat (Diekman & Malcolm, 2009) or carbohydrates (Marinangeli et al., 2019) is healthy eating. But many would also say to just strive for a healthy balance (Croll et al., 2001; Ishak et al., 2020). Essentially, healthy eating seems to be primarily interpreted on one's life context and individual circumstances. This is in line with the World Health Organization's suggestion to balance energy intake with energy expenditure to avoid unhealthy weight gain and to keep total fat intake below 30% and the consumption of free sugars below 10% of the total energy intake (World Health Organization, 2020).

It seems that our eating patterns are largely influenced by our perceptions on eating. For example, there were patients who have developed a syndrome known as "chronic dieting"

(Grodner, 1992), a situation wherein a person is over worried about their weight or body image and proceeds to restrict their food choices for weight loss. However, contrary to what they were trying to achieve, they regain the weight. Therapies such as Cognitive Behavioral Therapy (CBT) and Cue-Exposure Therapy (CET) have been shown to alleviate these unhelpful eating behaviors by helping patients to modify their eating habits and to be mindful of their food intake. Other patients, however, developed eating disorders such Anorexia Nervosa and Bulimia Nervosa. These eating behaviors can be detrimental to health, and some can lead to death (Fairburn & Cooper, 2007; Fairburn & Harrison, 2003; Treasure, 2016; Treasure et al., 2010). For patients affected with binge-eating disorder, CBT has been shown to be effective and is now considered as the gold standard for treating the condition. However, only 30-50% of those patients who have undergone the therapy completely recover, while other experience relapses (Gutiérrez-Maldonado et al., 2018). Consequently, some psychologists think that these eating conditions may be similar to an addiction to drugs, alcohol, or nicotine (Gold et al., 2003).

A common diagnostic criterion for these addictions is cravings, so CET was introduced to address this issue. Wardle (1990) presented an approach whereby a continuous exposure to triggering cues can develop a new conditioned response or behavior that will eliminate the unhelpful behavior through extinction (gradual weakening of a behavior). Its objective is to identify cue reactivity (cravings) and to teach patients coping skills when exposed to triggering cues (Jansen, 1998). Prior to the utilization of CET for binge-eating disorder, it was suggested that treatment might be achieved through "self-management" by limiting exposure to extrinsic environmental cues that may develop the craving. Staiger, Dawe, and McCarthy (2000) also investigated this on bulimic women. In their study, 17 bulimic and 17 healthy (no EDs) women were exposed to their favorite food cues (including visual, olfactory and gustatory cues). The bulimic group showed higher levels of stress and urge to eat, lower confidence to resist the food, and loss of control compared to the healthy or control group. Similar results were also reported by Jansen et al. (2003) who conducted a study on the influence of food cues on overweight children, and on how they can predict overeating. As expected, overweight children who were exposed to palatable food cues (e.g., M&M's, Milky Way, cake, nuts) by taste testing developed higher levels of appetite (measured through salivation magnitude).

Other studies, however, suggest that olfactory stimuli can also be used to reduce food cravings. Several studies showed that olfactory cues may be used as coping mechanisms to prevent the development of food cravings. For example, smelling a non-food odorant or an uncommon odorant after being exposed to highly delectable images of food can curb cravings (Kemps et al., 2012; Kemps & Tiggemann, 2013). This implies a relationship between olfactory cues and our perception of food.

Although this method is quite successful for some, another study has also suggested a theory that some of the pro-anorexia communities use "food porn" (enticing images of food) to maintain their unhelpful eating behaviors. The theory implies that food porn can be used as an alternative process to eating. Instead of eating real food, anorexic individuals "eat with their minds," which may curb their food craving but prolong the illness (Lavis, 2017). This is in line with the findings of a related research that sustaining mental imagery of food cues may suppress cravings (Kemps & Tiggemann, 2015).

2.2 Sensory Interfaces and Mixed Reality Technologies in Food and Eating

2.2.1 Olfactory and Gustatory Interfaces

Sensory interfaces for visual and auditory systems are quite well developed due to the fact these systems uses physical stimuli for sensation. The chemical senses, on the other hand, rely on chemical stimuli which is a challenge to deliver and control. However, over the past few decades, researchers have started to study this area. Between the gustatory and olfactory systems, research on olfactory interfaces has been growing recently.

Olfactory interfaces were firstly used to provide additional information to a user through olfactory cues. This domain had seen a growing interest in the last couple of decades. These interfaces commonly deliver smells by blending chemical substances and delivering them through the use of vaporization (Amores & Maes, 2017; Yamada et al., 2006; Yanagida, 2012) and valves (T. Nakamoto et al., 2009; T. Nakamoto & Minh, 2007; Yamanaka et al., 2002). The challenge with olfactory interfaces is that the number of scents that can be delivered at one time is limited. Moreover, once the scent is emitted through the air, it can be difficult to remove. Hence, there are several studies which attempted to localize scent delivery (Dobbelstein et al., 2017; Wang et al., 2020; Yamada et al., 2006).

The Sensorama simulator is probably one of the earliest inventions that have incorporated olfactory cues as part of its experience. In the simulator, users were able to experience riding a motorcycle in the city of New York and hear the buzzling streets, feel the wind and smell the city (Morton L. Heilig, 1962). A similar study by Nakamoto and Yoshikawa (2006) attempted to use an olfactory interface for exploring how much olfactory cues can influence a user's attention when watching a movie. Several studies have also used olfactory displays in games. Nakamoto et. al. (2008) developed an olfactory interface that can blend scents in real time. They tested this interface on a cooking game where players were asked to cook a curry dish. The scent emitted by the interface depends on the ingredients used by the player. Ranasinghe et. al.(2019) also developed an horror adventure game called "Tainted" where players takes the role of an amnesiac being chased by a vampiric being. In their game, they provided their players olfactory cues (from a diffuser) that can communicate game states or hints and even evoke emotional feelings of hear. Their study showed that most players appreciated the additional information provided by olfactory cues.

Compared to olfactory interfaces, gustatory interfaces requires sensation from the tongue, olfactory cues, auditory cues (i.e., the sound created when on bites) and haptic cues (i.e., structure and texture of food) to display taste making it more complex to present. In addition to that, gustatory cues have to be directly delivered inside the mouth. Currently, stimulation delivered to tongue can be invoked using chemical substances, electrical stimuli and thermal stimuli (Vi et al., 2017).

One of the earliest works on gustatory interfaces that included not only chemical stimulation but the other senses was the Food Simulator (Iwata et al., 2004). This display can present chemical sensations and as well as the texture of the food. Chemical sensations were dispensed through an injection pump when the user bites onto the device. Moreover, the action of biting would also produce an auditory cue that is delivered through a bone conduction headphones that can emulate food texture. Another similar work was done by Nijima and Ogawa (2016). In their study, they proposed a method of using electric muscle stimulation to emulate food texture of a virtual food. Food texture was generated through a food texture database that they have generated using EMG (electromyography) sensors positioned around the masseter muscle (muscle used for mastication or chewing located around the lower jaw). Other gustatory interfaces were explored in a playful manner. In an exploratory study, Murer et. al. (2013) proposed an haptic input called LOLLio which can be used for gaming. This lollipop can deliver sweet to sour tastes. In that same year, Moser and Tscheligi (2013) used LOLLio in a study with 10 children to assess their game experiences while playing a game. Their results showed that the children was effective in providing positive game experiences.

2.2.2 Mixed Reality Technologies

The combination of eating and MR technologies (Milgram et al., 1994) is an area where many research questions are yet to be answered. For example, Persky (2018) recently demonstrated that a parent's child feeding behavior using a VR buffet is highly correlated to their real-world behavior and provides an additional study tool in what is a logistically challenging area to investigate. Moreover, Fox et al. (2009), demonstrated how even the social presence of an eating avatar in a virtual environment can encourage women, but interestingly not men, to eat food. Some studies have used VR, for example, as an assessment tool to study substance use disorders (Worley, 2019) and eating behaviors or disorders. Likewise, VR has been used to treat those displaying eating disorder symptoms and obesity by simulating and addressing food cue triggers (Ferrer-Garcia et al., 2015; Gutiérrez-Maldonado et al., 2018). Gutiérrez-Maldonado et. al. (2017) published a handbook containing the use of VR for EDs. It summarizes how research has evolved in this area over the past 20 years and demonstrates that the results produced in VR are comparable to physical or clinical settings. To give an example, a study was conducted to examine the correlation between environmental cues and anxiety and depression in patients affected by EDs using VR. Participants showed higher levels of anxiety when exposed to an environment (kitchen and restaurant) with high-calorie foods, due to their fear of weight gain (Gutiérrez-Maldonado et al., 2006). Gorini et al. (2010) have also reported on and supported the use of VR in CET. In this preliminary study, participants undertook three exposure tasks to: real food cues (RF), photograph food cues (PH), and virtual food cues (VRF). In each task, participants were exposed to food cues for 30 seconds. The RF task included exposure to calorific savoury and sweet foods. The PH task included exposure to a slideshow of RF foods on a computer screen. Lastly, the VRF task included exposure to virtual food with the use of an HMD and joystick to interact with the virtual food. Results showed that participants developed emotional responses (particularly anxiety during the study) from all these cue groups. In addition, VRF were found to be comparable to RF, but slightly better than PH. Several years later, the same methodology was tested by Ledoux et al., (2013) for food cravings. At first, participants (all non-dieting females) were assigned to a diet condition (normal or monotonous). Secondly, participants were exposed to neutral VR cues (nature scenery), RF cues (chocolate, donuts, and cookies), PH cues, and VRF cues for three minutes each, while subjective (using a questionnaire) and objective (salivation magnitude) measurements of food cravings were collected. Their results showed that VRF cues were not as effective as RF cues, and just (or equally) comparable with PH cues. Notably, they suggested, that perhaps the realism in the VR was lacking and the contextual cues were rather distracting. Recently, van der Waal et. al. (2021) tested similar variables and had similar results.

One study explored how eating can be part of a VR entertainment game. Arnold (2017) developed a two-player survival VR game wherein the players' goal was to scavenge food on the island where they were stranded, as well as to find tools (e.g., flare gun) that could help them get off the island. The first player wears a VR head-mounted display and the second player feeds the first player, requiring them to work together to survive the game.

Harley et al. (2018), described how to create simple virtual scenarios (e.g. picnic in the forest, relaxing in the beach) that can enable someone to enjoy food and drink in VR through the use of low-cost non-digital props (e.g. heated sand, space heater), which is quite similar to the "human actuators" in a system called TurkDeck (Cheng et al., 2015).

A startup company called "Project Nourished" (2018) works on a VR gastronomical dining experience. They propose this virtual experience with non-calorific foods which have been 3D-printed using an algae called "agar-agar". In similar work, two studies investigated methods for how to eat food in virtual environments. The first study had participants eat real cup noodles in a virtual park by switching between the real and virtual environments depending on the HMD pitch angle. If the participant is looking (down) towards the food, the display will change to the real environment. Meanwhile, if the participant is looking around, the virtual park is displayed. Their participants found the experience good. (Korsgaard et al., 2017). The second study is more of an Augmented Virtuality experience. In this study, participants were asked to eat real desserts in a virtual kitchen. Participant's arms, desserts and cutlery were brought into the virtual environment. The study reported a low technology acceptance of the system due to technical limitations and varied user preferences (Korsgaard et al., 2019). Another study by Li and Bailenson (2018) also explored how haptic and olfactory cues can influence satiation. In their study, participants were shown holding virtual chocolate donuts and were asked to count the number of sprinkles on the donuts. Some of them were either given a fake donut (haptic cue) to hold, some were provided with a chocolate scent (olfactory cue) through a cotton swab and some do not have any of these additional cues. After which, they were asked to help themselves to real donuts. Their study found out that those participants who got to hold the fake donut and smell the chocolate scent ate fewer donuts than others.

On the other side of the MR continuum, researchers have also attempted to use Augmented Reality (AR) for creating novel eating experiences. The Metacookie+ (Narumi & Takuji, 2016) is a marker-based AR system used for modifying the perceived flavor of a cookie by superimposing visual and olfactory flavor cues onto a plain cookie. A similar system was also made with ramen noodles, it used GAN (Generative Adversarial Nets), a machine learning framework to dynamically modify the visual appearance of the ramen (Nakano et al., 2019). The goal of another system, called "Augmented Satiety," was to change the perceived level of satiation by increasing or decreasing the size of food through the use of visual cues. In this study, participants were asked to help themselves to cookies and water while wearing the AR HMD. Some of them were provided with visual representation of shrunken cookies, normal cookies and enlarged cookies. Those who had enlarged cookies reported to have eaten less cookies than those who ate shrunken cookies (Narumi et al., 2012). In another study, an AR projection mapping system was used to successfully enhance food appearance to make them look more delectable (Fujimoto, 2019).

2.3 Conclusion

This chapter discussed relevant previous research that is related to this thesis such as human eating behaviors, food preferences, flavor perception and the field of HFI. It described what influences our eating behaviors; including eating disorders and food cues. Moreover, it summarized research that demonstrated how our eating behaviors can easily be influenced by things around us – by things we perceive through our senses. Our food preferences, which are associated with flavor, affect what we eat or not eat. Lastly, it looked at the current state of food-related research, eating and MR technologies which this thesis is most closely related to.

From this research review, it is evident that eating is a multifaceted experience including food acquisition, food preparation, cooking, plating, and not merely limited to the process of when we put food into our mouths. Therefore a variety of considerations have to be made when creating or designing food interfaces for VR.

3 Development of Food Cravings in Virtual Reality

This user study explored mainly the effects of olfactory and interaction cues on perceived food cravings when exposed to virtual food. In addition to that, this study was closely based on the study of Ledoux et al. (2013) where they evaluated how different visual cues of food can induce higher food cravings. This study was presented as a poster at the *25th IEEE Conference on Virtual Reality and 3D User Interfaces* in Reutlingen, Germany.

3.1 Motivation

As discussed in Chapter 2, research on food and eating in VR is evidently sparse. It could potentially be due to the fact that at the current state of VR technology is not mature enough to enable us to further explore this domain. Another reason could be that the experience of eating includes the different senses, thereby requiring more effort to control different variables. Nevertheless, before attempting to explore such domain, we need to ask ourselves of these questions:

- Would anyone want to eat in VR?
- How do we determine if people would be inclined to eat real food while wearing an HMD?

To answer these questions, we had a look at different factors (i.e., hunger hormones, exposure to sensory cues) that influences our eating behaviors and food choices as discussed in section 2.1.2. Evidently, these factors affect our urges to eat food. Hence, these urges to eat or food cravings were used in this study to measure and answer the questions previously stated above.

Currently, food cravings are studied predominantly in the domain of CETs and CBTs. These therapies help people, especially those with EDs, by teaching them how to cope when exposed to certain food cues as seen in section 2.1.1. Although these procedures worked for many, there was still an issue on controlling the setting or environment of the therapy which is typical in vivo exposures and issues on helping people visualize scenarios or recount memories to promote emotional involvement. Therefore, some researchers steered towards using more advanced technologies such as VR to broaden their set of assessment and treatment tools (Gutiérrez-Maldonado et al., 2018).

Over the past decade, research on VR-CETs have increased substantially and have been shown to be quite effective and helpful, not only for people with EDs but also for healthy people. Thus, the researcher came to a decision to base the methodologies of this domain to this user study. However, this domain have had mixed results on its efficacy which is disputed in its community. Moreover, research have largely focused on visual food cues. Only a handful of studies (Arnold, 2017; Narumi et al., 2011) extended the study to the chemical senses (olfactory and gustatory) which is arguably a lot more challenging but play a larger role in our eating experience (Spence et al., 2017). Thus, this study hoped to revalidate earlier efficacy findings of VR-CETs and to extend the exposure through olfactory stimulation and active participation of the user.

3.2 Participants

A total of 30 people participated in the study (22 female, 8 male). Participants were restricted to those over 18 years of age, with no known eating disorders or known food allergies. Most (18) were aged between 18 to 24 years, while 10 were between 25 to 34, and two were between 35 to 44.

All participants were instructed to abstain from any food or drink for two hours prior to their scheduled session. All participants confirmed that they did not have any food within those hours, although 10 indicated that they had consumed a caffeinated beverage within two hours before their session.

Most participants (19) stated that they generally liked chocolate chip cookies very much, two reported a low liking and nine quantified their liking of chocolate chip cookies in the mid-range. Fourteen participants indicated they had some experience with VR before, whereas 16 of them said it was their first time to use VR.

The study was approved by the ethics committee of University of Canterbury and all participants gave written informed consent (see Appendix A). Participants were compensated with a voucher for a nearby shopping mall.

3.3 Study Design

A within-subjects design was used, and the order of the conditions was derived from a subset of a 7x7 Latin square including the neutral baseline which was an exposure to a white brick wall (Figure 1a). The exposure conditions were:

- Real chocolate chip cookies (RC, see Figure 1b)
- Photo of chocolate chip cookies (PHC, see Figure 1c)
- Virtual chocolate chip cookies (VC, see Figure 1d)
- Virtual chocolate chip cookies with chocolate scent (VCO)
- Virtual chocolate chip cookies with interaction (VCI)
- Virtual chocolate chip cookies with chocolate scent and interaction (VCOI, see Figure 1e)

In each condition, the degree of perceived food cravings were measured. Subjectively, participants completed the Food Craving Questionnaire-State (FCQ-S) and rated their Urge to eat cookies (UC). The FCQ-S (Cepeda-Benito et al., 2000) was used for collecting self-reported food cravings at the time of the testing, while their UC (Ledoux et al., 2013) was measured using a visual analog scale with ratings from 0 to 100, 0 as weakest and 100 as the strongest urge. Objectively, the salivation magnitude (Epstein et al., 1995) was used as a physiological measure of food cravings. This magnitude was derived from taking the difference between the pre- and post-weights of the cotton dental rolls using precision scales.

3.4 Research Aim and Hypotheses

This study evaluates the following three hypotheses:

- H1: Based on the adapted study, virtual cookies (VC) would evoke higher food cravings than real cookies (RC), photo of cookies (PHC) and the neutral baseline (NB).
- H2: Virtual cookies with chocolate scent (VCO) and virtual cookies with interaction (VCI) would both evoke higher food cravings than just virtual cookies (VC).
- H3: Virtual cookies with chocolate scent and interaction (VCOI) would evoke higher food cravings than VC, VCO and VCI.

3.5 Procedure

At the beginning of the experiment, participants were briefed about the study and given the opportunity to ask questions. After that, they were asked to sign an informed consent form and complete a demographics questionnaire.

Before each condition, participants were asked to take three pre-weighed cotton dental rolls from a bowl and place two rolls buccally (between the cheek and the lower gums) and one sublingually (under the tongue) inside the mouth, targeting the parotid and sublingual salivary glands, respectively. These cotton rolls were used to collect saliva from the participants to physiologically measure food cravings. Also, they were asked to wear the provided noise-canceling headphones to block out noise from outside.

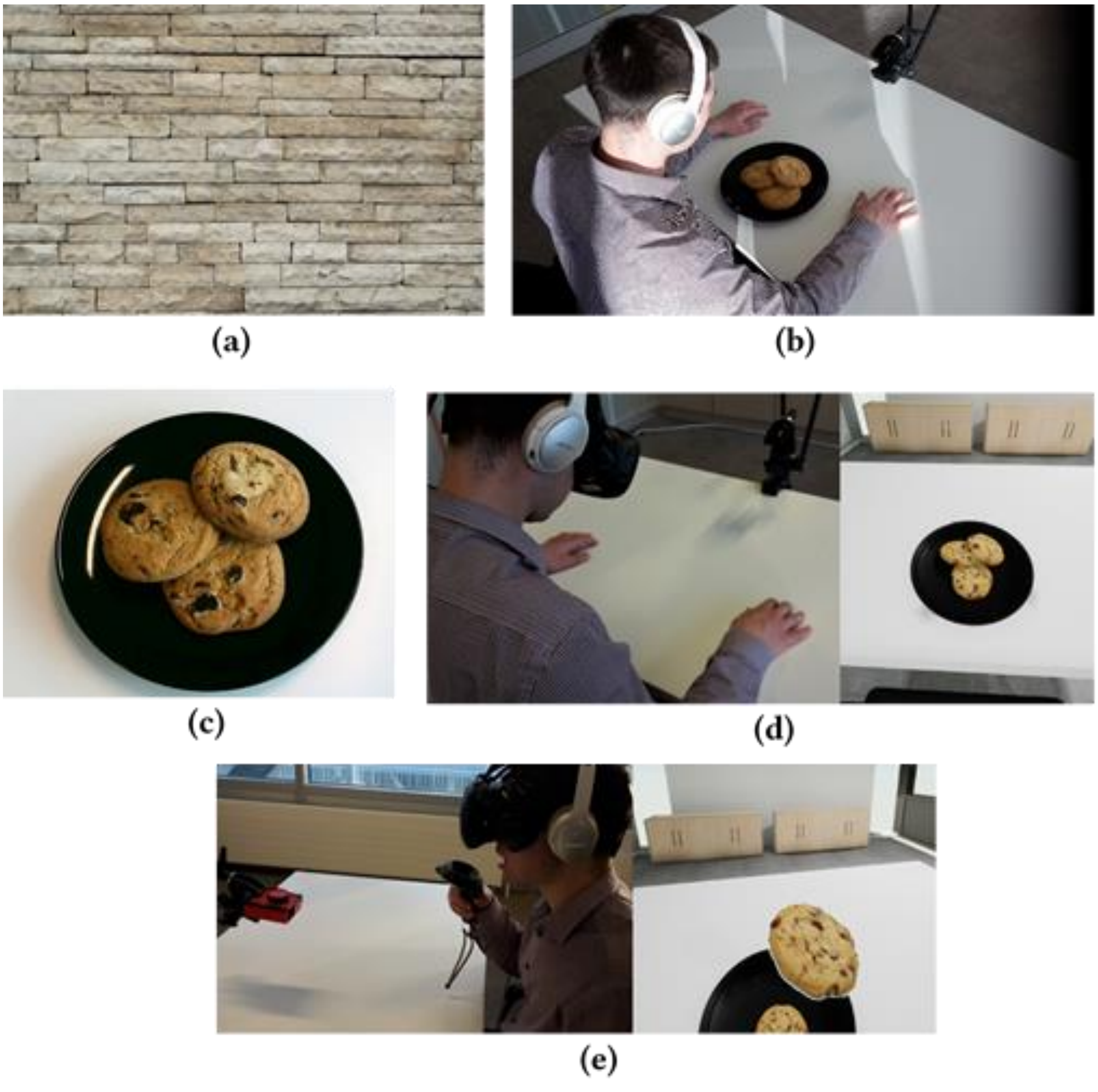

*Figure 1(a) NB: white brick wall. (b) A user exposed to real cookies. (c) Photo used for the PHC condition. (d) A user exposed to virtual chocolate chip cookies and their view in the virtual world. (e) A user exposed to virtual chocolate chip cookies with choco*late scent and interaction.

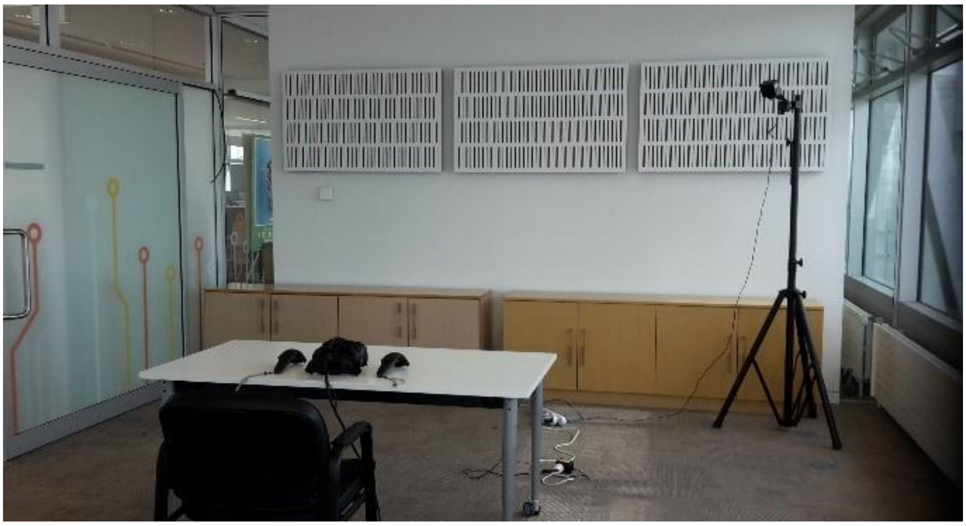

Figure 2: The actual experiment room where the virtual room was based from.

In most of the conditions, participants did not have to do anything besides to sit and to observe either real or virtual chocolate chip cookies (or a brick wall for NB). For the VR exposure conditions that required interaction (VCI and VCOI), they were provided with an HTC controller that enabled them to pick up virtual cookies. For tasks that included the use of the olfactory device (VCO and VCOI), this device was only put in place after the participant had put on the VR headset (HTC Vive), so participants were unaware of this device that produced olfactory cues. Following these conditions (involving synthetic olfactory cues), the researcher opened the windows and sprayed the room with the odor-neutralizer. Each task lasted for two minutes, after which the subject was instructed to remove the cotton rolls from her or his mouth, put them on a provided dish, and have a sip of water which acted as a "neutralizer" between each task. After doing so, a two-minute break started, during which

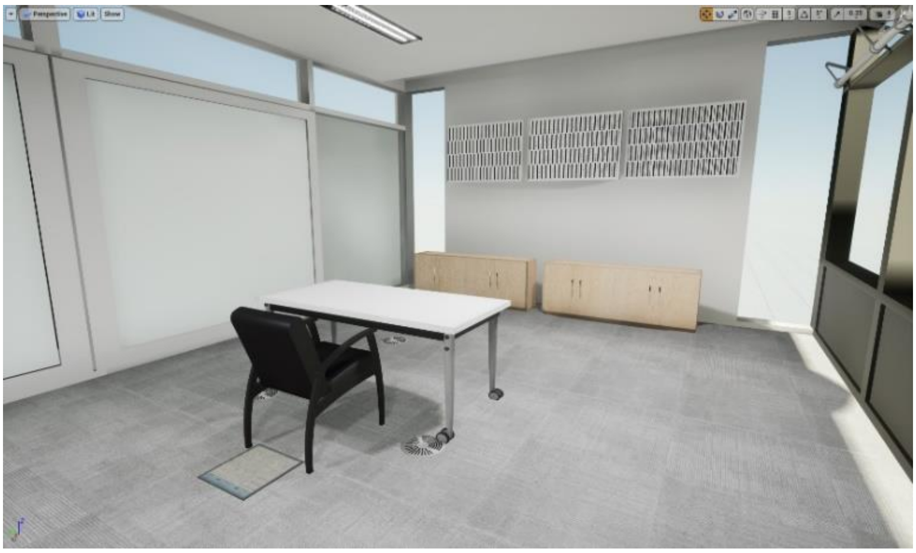

Figure 3: Virtual experiment room

participants were asked to rate their urge to eat the cookies and to complete a food craving questionnaire. Meanwhile, the used cotton rolls were weighed and the data recorded.

3.6 System

The virtual test environment was a virtual replica of the experiment room (see Figures 2 and 3). This was to ensure that our participants concentrate on the task in front of them by making the environment similarly uninteresting as the room in which they were physically in. The researcher created the virtual room (including all 3D meshes and textures except the chair mesh) using Autodesk Maya 2017[1] and then imported into Unreal Engine 4[2] (UE4). In the virtual room, the first few objects that a participant would find were a table with a white surface and a black plate with three chocolate chip cookies on it. This environment was delivered using the HTC Vive[3], and its motion controllers were used to interact with the virtual cookies. The virtual room was rendered on an Intel Core i7-7700k 4.2GHz (eight cores) with 32GB of RAM and a NVIDIA GeForce GTX 1080 Ti graphics card running Windows 10.

Previous CET studies have used different kinds of food for exposure. For this study, cookies were chosen as the food cue since it is easy to acquire and store. It is also known that chocolate is liked by many (Pelchat, 1997; Rozin et al., 1991). The real cookies used for the exposure were Cookie Time's "Original Chocolate Chunk Cookies"[7]. These cookies are approximately nine centimeters in diameter. The virtual cookies[8] (see Figure 4) that was used were also scaled around the same size as the real ones. The black plate on where the cookies were presented was approximately 26.5 centimeters in diameter.

Figure 4: Virtual chocolate cookies

[1] https://www.autodesk.co.nz/products/maya/overview
[2] https://www.unrealengine.com/en-US/
[3] https://www.vive.com/nz/product/#vive
[7] https://munchtime.co.nz/shop/original-chocolate-chunk-85g-cookie-time-cookie-unit/
[8] https://www.turbosquid.com/3d-models/3d-cookie-chocolate-model/1099460

Figure 5: (Right) Cotton dental rolls; (Left) Precision scales

To physiologically measure food cravings, three Amtech cotton dental rolls[9] were used (see Figure 5) with small variations in sizes (8mm x 38mm) to collect saliva produced by the participants. After which, two high-precision scales were used (one with a 0.001g level of precision[10], the other a 0.01g level of precision[11]; see Figure 5 right) to independently weigh the cotton dental rolls and therefore ensure accuracy of weight readings.

A simple olfactory device was designed (see Figure 6) to deliver the scent (chocolate) to the participant. This device comprised of a small blower fan which drew air from above, some cotton balls (approximately two shredded cotton balls weighing about 0.50g each) soaked with chocolate scent oil (approximately 1ml) and a red casing which was designed using Tinkercad[12] and 3D printed in MakerBot Replicator 2X[13]. To neutralize the room from the chocolate scent, an X-O odor-neutralizer[14] was used after each condition that involved olfactory cues. The olfactory device is clipped onto a Manfrotto[15] mounting arm with a clamp[16] which is then attached to the table. The distance between the olfactory device and the participant is approximately 35 to 40cm (see Figure 7).

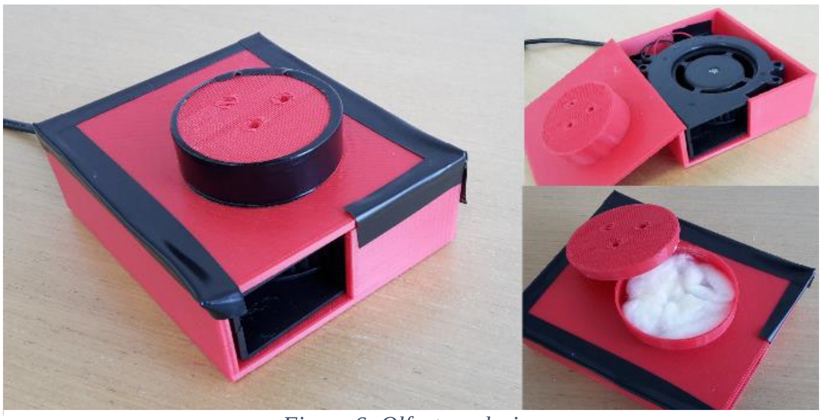

Figure 6: Olfactory device

[9] https://www.amtech.co.nz/dn126.html?popup=true
[10] https://www.trademe.co.nz/business-farming-industry/industrial/measuring-scales/auction-1434247768.htm
[11] https://www.trademe.co.nz/business-farming-industry/industrial/measuring-scales/auction-1429156906.htm
[12] https://www.tinkercad.com/
[13] https://www.makerbot.com/makerbot-replicator-2x/
[14] https://www.amazon.com/Odor-Neutralizer-Ready-Spray-8-Ounce/dp/B0002XJ15A
[15] https://www.manfrotto.com/global/single-arm-3-section-196ab-3/
[16] https://www.manfrotto.com/global/virtual-reality-super-clamp-m035vr/

Figure 7: Approximate distance between the olfactory device and the participant

3.7 Results

Data analysis was carried out with SPSS 25 for Windows. The alpha level for statistical significance was set to 0.05 and to 0.1 for marginal significance. Calculated salivation magnitude, FCQ-S and UC ratings were analyzed with a repeated measures ANOVA, testing within-subjects effects and pairwise comparisons using Bonferroni adjustment. Sphericity was tested with Mauchly's test and when violated, the degrees of freedom were corrected with Huynh-Feldt for $\epsilon > 0.75$ and Greenhouse-Geisser for $\epsilon < 0.75$. Table 1 shows the means and standard deviations for this study.

Table 1: Summary of means and standard deviations of food craving measures

	Food Craving Measure					
Exposure Conditions	**Sal. Magnitude [a]**		**Urge to eat cookie [b]**		**FCQ-S [c]**	
	M	SD	M	SD	M	SD
RC	2.12	1.191	52.90	13.944	62.63	27.756
PHC	2.03	1.006	47.40	16.738	38.50	27.341
VC	2.04	1.409	49.10	16.056	41.76	25.211
VCO	1.99	0.983	52.36	15.173	54.73	28.820
VCI	1.77	0.994	48.60	15.078	47.00	30.530
VCOI	2.04	1.270	53.63	16.102	57.06	31.495
NB	1.72	0.869	41.40	18.024	20.36	24.159

[a] In milligrams, [b] Scores from 0 to 100, [c] Scores from 15 to 75

RC - Real Cookie, PHC - Photo Cookie, VC - Virtual Cookie, VCO - Virtual Cookie and Olfactory Cues, VCI - Virtual Cookie and Interaction, VCOI - Virtual Cookie, Olfactory Cues and Interaction, NB - Neutral Baseline;

3.7.1 Comparisons Between VR and Real-World Exposure Conditions

This section describes the results related to the first hypothesis, whether we are able to

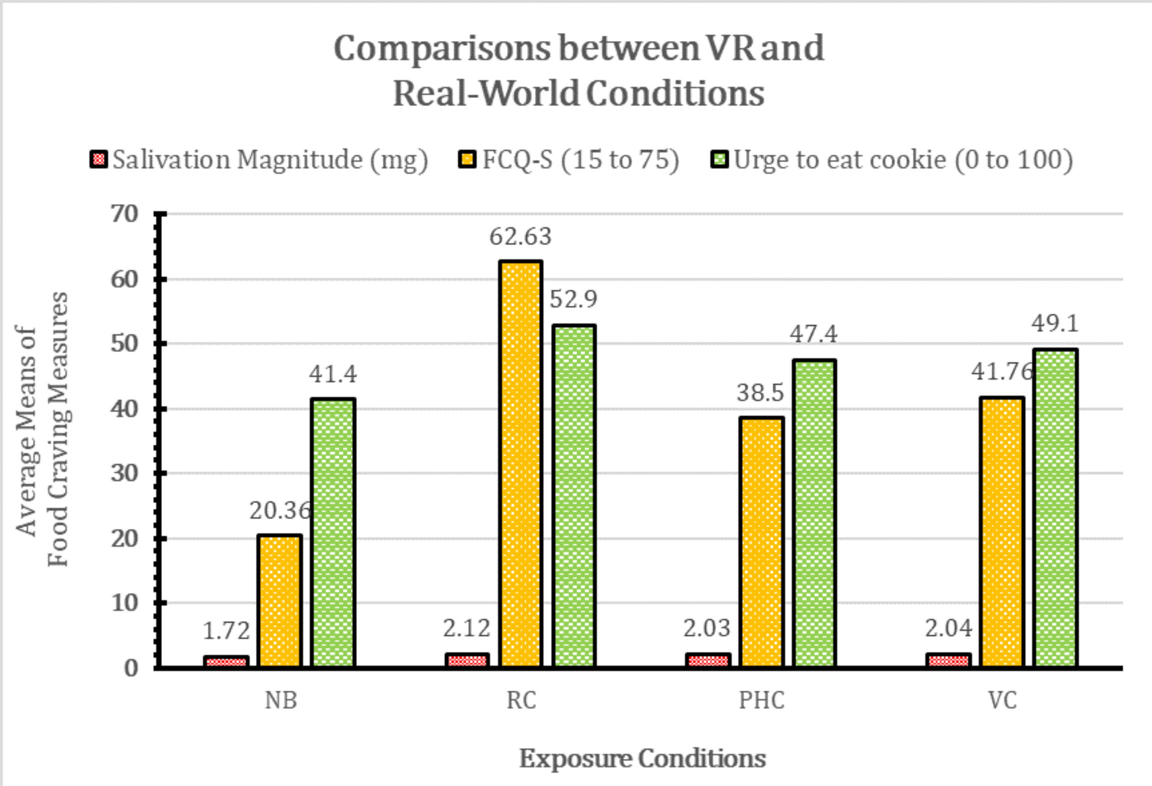

Figure 8: Comparisons between VR and Real-World Conditions

use VR cue exposure to elicit comparable results (food cravings) to those in real-world cue exposure. The VR condition described here is VC while the real-world conditions are RC, PHC and NB. The FCQ-S has 15 items, each item being rated between one and five, and the total rating ranging from 15 to 75. See Figure 8 for the mean comparisons.

The analysis showed strong significant differences of FCQ-S scores between the exposure conditions, $F(1.716, 49.767) = 15.621$, $p < 0.001$, $\eta^2p = 0.350$. Pair-wise comparison showed that RC is significantly different to PHC ($p = 0.035$). VC is significantly different than NB ($p < 0.001$) while it has no significant differences to RC ($p = 0.161$) and PHC ($p = 1.000$).

3.7.1.1 Salivation Magnitude

The results showed that there was a tendency towards a difference between the exposure conditions, $F(2.649, 76.821) = 2.377$, $p = 0.084$, $\eta^2p = 0.076$. A pair-wise comparison showed that two conditions were different from the neutral baseline: RC and PHC were significantly larger ($p = 0.043$ and $p = 0.034$, respectively). VC was not significantly different from NB ($p = 0.364$).

3.7.1.2 Food Craving Questionnaire - State

The data showed that the intensity of participants' urge to eat the cookies in the different conditions was significantly different, $F (2.236, 64.843) = 33.157$, $p < 0.001$, $\eta^2p = 0.533$. RC and NB were significantly different from all the other conditions (all $p < .001$). While there was no significant difference between the data for PHC and VC ($p = 1.000$).

3.7.2 Comparisons Between VR Exposure Conditions

This section describes the results related to the second and third hypotheses, that the addition of olfactory cues and that the possibility to interact with the virtual food increases the effects of VR cue exposure. The VR conditions included here are VC, VCO, VCI and VCOI. To assess the effect of olfactory cues VC, VCO and VCOI were compared, i.e. the plain virtual reality condition (VC), the virtual reality condition with olfactory cues (VCO) and the virtual reality condition with both olfactory cues and the interaction possibility. To assess the effect of interaction cues, VC, VCOI, as well as the condition that allowed interaction but without olfactory cues (VCI) were compared using the statistical analysis approach described at the beginning of this section. Figure 9 shows a chart with the means of the measurements in these four conditions.

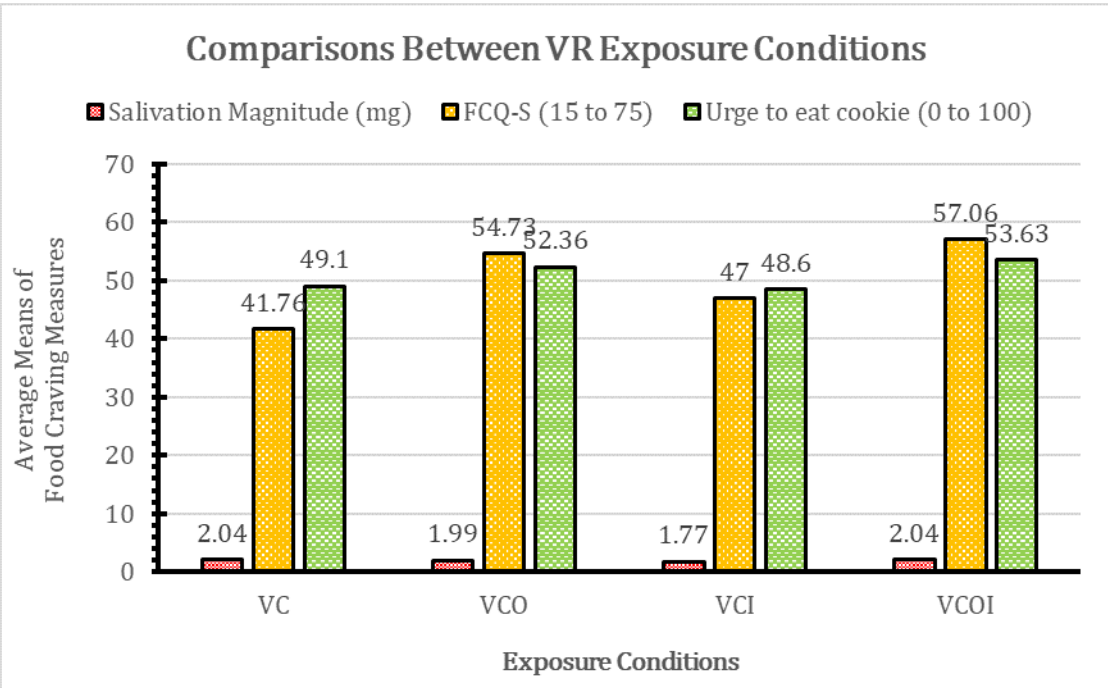

Figure 9: Comparisons between VR Exposure Conditions

3.7.2.1 *Urge to Eat Cookie*

UC ratings were significantly different for olfactory cue comparison conditions, $F(2, 58) = 15.986$, $p < 0.001$, $\eta^2p = 0.355$. Pairwise comparisons showed that VCO ($p < 0.001$) and VCOI ($p < 0.001$) were significantly different from VC, while VCO and VCOI did not differ significantly ($p = 1.000$). Data showed that the conditions to assess the effects of interaction also resulted in significantly different urges to eat the cookies, $F(2, 58) = 10.710$, $p < 0.001$, $\eta^2p = 0.270$. VC was not statistically different from VCI ($p = 0.134$) but was significantly different from VCOI ($p < 0.001$), while VCI and VCOI showed a trend towards a significant difference ($p = 0.059$).

3.7.2.2 *Salivation Magnitude*

Neither the data from the three conditions compared to assess the effects of olfactory cues ($F(2, 58) = 0.028$, $p = 0.973$, $\eta^2p = 0.001$) nor the three conditions with interaction cues ($F(2, 58) = 1.110$, $p = 0.336$, $n^2 p = 0.037$) were significantly different from each other in terms of salivation magnitude.

3.7.2.3 *Food Craving Questionnaire – State*

Food cravings were significantly different for the three conditions that were compared with each other to assess the effect of olfactory cues, $F(2, 58) = 5.726$, $p = 0.005$, $\eta^2p = 0.165$. Similarly, interaction cues had significant effects on food cravings, $F(2, 58) = 7.331$, $p < 0.001$, $\eta^2p = 0.202$. In terms of olfactory cues, pairwise comparisons showed that VC was significantly different from VCOI ($p = 0.023$), while VC and VCO had a tendency towards significance ($p = 0.084$). VCO and VCOI were not significantly different ($p = 0.824$). For interaction cues,

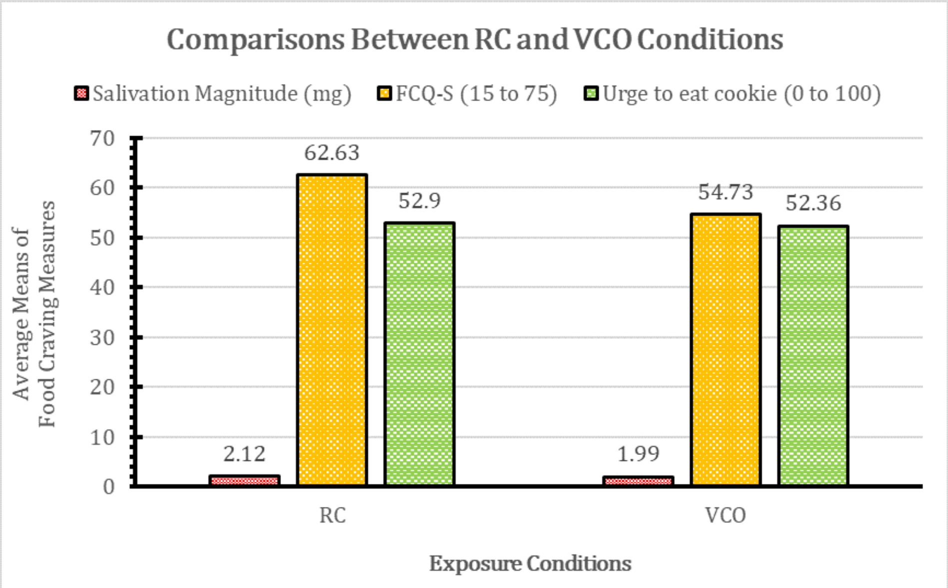

Figure 10: Comparison between RC and VCO conditions

VCI showed no significant difference from VC ($p = 1.000$). Meanwhile, VCOI showed significant differences from VC ($p = 0.023$) and VCI ($p = 0.004$).

3.7.3 Comparison between RC and VCO

This section describes an additional comparison between RC and VCO. Among all the conditions in this study, RC and VCO are the most similar in terms of setup as it is possible to see and smell the cookies in both RC and VCO. For this section, salivation magnitude, FCQ-S and UC ratings were analyzed using a paired-sample t-test. Figure 10 shows the mean comparison for RC and VCO.

In terms of Salivation Magnitude ($t(29) = 0.789$, $p = 0.437$) and UC ratings ($t(29) = 0.339$, $p = 0.737$) there was no significant difference in the scores for RC and VCO. Whereas, their FCQ-S scores were significantly different, $t(29) = 2.952$, $p = 0.006$. This provides some support for VR as a means to simulate food and comparable to real food experiences, although the reasons for the significantly lower FCQ-S in the VCO compared to the RC need to be further investigated.

3.7.4 Summary of Comments

Qualitative feedback data was summarized using thematic analysis (Nowell et al., 2017). The themes identified were "Bizarre", "Like a game", "Disappointing" and "Stimulating". Some participants, who had never experienced VR before, thought the setup was strange, but in a surprising way. One participant described the experience as "trippy." Nevertheless, many of them thought the interaction was intuitive. Participants who had experience with VR and who also played video games thought the interaction was more like a game. Most of them threw the virtual cookies across the room or just simply played with them in the VC conditions with added interaction possibilities. However, several participants stopped interacting with the virtual cookies after a short time. When asked for a reason at the end of the experiment, they mostly described a feeling of disappointment knowing they cannot eat the virtual cookies. Furthermore, several participants mentioned that in NB conditions, they thought of other matters or the previous cookies that they were exposed to. Overall, participants thought the olfactory cues were pleasant and some of them even mentioned it smelling like "freshly baked cookies" which was making them hungry.

3.8 Discussion

There are several differences between Ledoux et al.'s study (2013) and the findings in this study. In the study by Ledoux et al., the condition that was intended as a neutral baseline, which was delivered first, produced significantly stronger food cravings (measured amount of saliva) than the RC, PHC and VC exposures. However, in this study, the salivation magnitude for the baseline, a white brick wall presented in a counterbalanced order with the other conditions, was never higher than any other condition. This difference can be explained with the fact that the neutral baseline was carefully selected in a pilot test before the main study. The effects of several photos, including pictures nature such as blooming flowers or mountains were evaluated. However, they were discarded because they produced increased magnitude of salivation. Ledoux et al. (2013) used a photo of a nature scene as their intended neutral baseline. Although, in this study, we were able to measure an increase of the magnitude of salivation from baseline 1.725g to values of 2g and above for all experiment conditions, the difference from the VC condition, with a higher standard-deviation between participants, was not statistically significant. Nevertheless, FCQ-S and UC responses were significantly above the neutral baseline for the VC condition as well. This supports the findings of van der Waal et. al. (2021) In addition, FCQ-S ratings for VC were not significantly different from PHC, however, it is significantly different from RC. Thus, in summary, these results partially support the first hypothesis that with the use of VR, it is possible to produce comparable effects on food cravings.

The evaluation of the second hypothesis, that the addition of olfactory cues increases the VR exposure effects, was also partially supported. This could be explained by the cross-modal interaction between the olfactory and visual cues (Krishna et al., 2014). While the urge to eat the cookies was significantly stronger for the VR conditions with olfactory cues, the difference in the FCQ-S ratings was only marginally significant, whereas there was no significant difference in the magnitude of salivation. Moreover, the addition of interaction was not significantly different for the VR conditions in UC, FCQ-S and salivation magnitude.

In contrast, the data does not support the third hypothesis. Allowing participants to interact with the virtual cookies with olfactory cues did not increase food cravings further. There was no statistically significant difference in UC, FCQ-S and salivation between the VR and the VR conditions that enabled interaction with the virtual cookies.

The comparison between RC and VCO provides an interesting result. RC and VCO had a similar setup. The only difference is that for RC, the olfactory cue was intrinsic (it was a real cookie) while for VCO, it was smell generated artificially. The salivation magnitude and UC ratings had no significant differences which might mean that these two conditions are comparable. However, it is hard to pinpoint why the FCQ-S ratings had significant differences. It may be speculated that the different odor attributes of the olfactory cues influenced the outcome: RC had a natural chocolate cookie smell whereas VCO could be interpreted to be more like chocolate fudge smell.

In summary, based on FCQ-S and UC ratings, VR can be used to elicit responses for cue exposure. In addition, olfactory cues can additionally increase food cravings above the neutral baseline. However, the combination of both olfactory and interaction cues does not increase this further.

Another consideration related to the usefulness of synthetic olfactory cues in VR is the *fundamental attribution error*[17] described by Spence et al. (2017), which defines the tendency of humans to attribute the experience elicited through stimulation of chemical senses to another sense such as vision. Hence, people could attribute the pleasure of eating a virtual cookie mostly to its visual appeal and discard the olfactory stimulation that also took place.

In addition the results of this study indicate that olfactory cues may be enough of an addition to increase the development of food cravings. With these considerations, the addition of olfactory cues does influence peoples' urge to eat in VR to some extent and can influence our VR eating experiences as well. Adding controller-based interaction with the virtual food, however, does not seem to produce increased effects and therefore additional ways to interact with the virtual food should be explored. This is examined in the next chapter.

[17] Note: Spence et al.'s definition of fundamental attribution error is different from its more common use in social psychology.

4 Food Interactions in Virtual Reality

Chapter 3 showed that olfactory cues increase the development of food cravings in VR. However, interaction with the virtual food did not show significant effects on food cravings. Importantly, from the verbal feedback in the previous study, it is evident that there is a need to provide a more realistic and tangible way to interact with the virtual food for users immersed in VR. This chapter explores VR food interactions more deeply.

4.1 <u>Motivation</u>

In last the chapter, we looked at the influence of sensory cues (mainly visual, olfactory and interaction cues) on the development of food cravings. Visual and olfactory cues increased the development of food cravings but not interaction cues. A likely explanation for this is that maybe the interaction with the virtual food using a controller was just "unnatural". Several studies have shown that carefully designed natural interactions do increase the sense of usability and sense of presence of a system (Bailey et al., 2019; Brondi et al., 2016). However, research on eating interactions or interfaces in VR is quite limited. Therefore, this study aimed to explore if our natural eating interactions in the real world would also apply in the virtual world. To test this, this study used the System Usability Scale (SUS) (Brooke, 2013) to measure perceived usability and the Igroup Presence Questionnaire (IPQ) (Schubert et al., 2001) to measure the sense of presence. The sense of presence in study is defined similar to IPQ's definition of presence: the sense of being physically present and being able to actively participate in a virtual environment.

4.2 <u>Participants</u>

A total of 24 people participated in the study (8 male, 12 female, 4 other) with most aged between 18 and 24 years, three between 25 and 34 and two between 35 and 44. Fourteen participants indicated that they play video games. Twenty were right-handed and four left-handed. All were recruited through Facebook using a poster (see Appendix B) and passed the inclusion criteria which was similar to the first user study. This study was approved by the ethics committee of University of Canterbury and all participants gave written informed consent (see Appendix B). Participants received a voucher for a nearby shopping mall for their participation in the experiment.

4.3 Study Design

A 2x2 within-subjects design was used for this study with two independent variables (hand fidelity and food interaction), each with two levels. The variable "hand fidelity" consisted of articulated (high-fidelity) and static (low-fidelity) hands, whereas "food interaction" consisted of bare-hand and utensil interactions with a short skewer. Therefore, four conditions were presented in a randomized and counterbalanced order:

- Articulated hands, bare-hand interaction (AB; see Figure 11a)
- Articulated hands, utensil interaction (AU; see Figure 11b)
- Static hands, bare-hand interaction (SB; see Figure 11c)
- Static hands, utensil interaction (SU; see Figure 11d)

4.4 Research Aim and Hypotheses

The purpose of this study was to investigate whether different hand fidelities and food interactions have any effect on perceived food-interaction usability and the effect on overall presence experienced by participants in VR. The following hypotheses were evaluated:

- H1: Sense of presence and perceived usability of the system is higher with articulated hands than static hands (i.e. higher fidelity display of hands is better)
- H2: Sense of presence and perceived usability of the system is higher with bare-hand interaction than utensil interaction (i.e. bare hand interaction is better)
- H3: Interaction effects of the two main factors:
    a) For articulated hands, the two types of food interaction would be similar in terms of sense of presence and perceived usability.
    b) For static hands, utensil interaction would score higher in terms of sense of presence and perceived usability than bare-hand interaction.

In the conditions with articulated hands (AB and AU), the virtual model of the hand included animations to mimic the movement of the real fingers. In contrast, in the conditions with static hands (SB and SU), the virtual hand model only contained static hand poses. In conditions that required bare-hand interactions (AB and SB), participants used their bare-hands

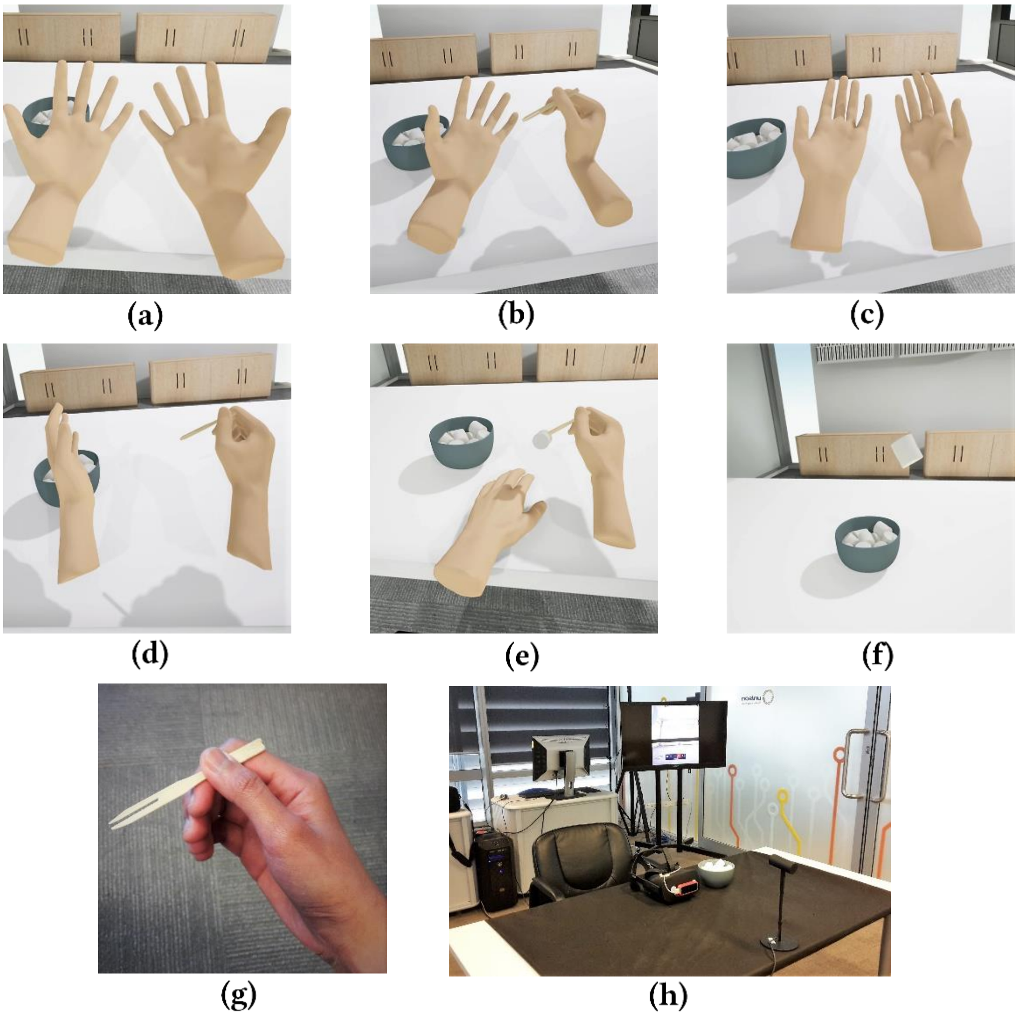

Figure 11: (a) and (b) show bare-hand and utensil interactions with articulated hands (high-fidelity) generated by the Leap Motion Controller, respectively. Meanwhile, (c) and (d) show bare-hand and utensil interactions with static hands (low-fidelity), respectively. (e) Image of how a virtual marshmallow looks on a skewer for SU. A similar process was performed for AU. (f) The "floating marshmallow" for bare hand interactions. (g) The required hand pose for utensil interactions. (h) The setup for the experiment. The monitor behind the participant served as a guide for the experimenter on when to attach or detach the marshmallows.

to pick up food and feed themselves. In utensil interactions (AU and SU), they used a skewer[18] instead. For each condition, participants were asked to eat marshmallows[19] from a real bowl, represented in the virtual environment by a registered virtual bowl filled with virtual marshmallows at the same location.

4.5 System

The virtual environment used in this study was the same as in the first user study, except that the black plate with chocolate chip cookies from the first study was replaced with a bowl

[18] https://www.disposabletableware.co.nz/collections/wooden-disposables/products/skewer-cocktail-fork-x-100
[19] https://lollyshop.co.nz/shop/MARSHMALLOW++FONDANT/White+Marshmallows.html?_ga=2.149491254.1463526933.1517899303-311383728.1507625576

of marshmallows (see Figure 11h). In this study participants used an Oculus Rift CV1[20] as HMD and tracking of the hands was performed with a Leap Motion Controller[21], software version 3.2.1 +45911 attached in front of the HMD (see Figure 11h). The default hand mesh provided by the Leap Motion Controller was used for the articulated hands. Meanwhile, the static hand mesh was also created from the default hand mesh with the skeleton animation removed.

In order to minimize the potential influence of tracking limitations (e.g., IR interference, noisy tracking due to light) of the Leap Motion Controller (Weichert et al., 2013), several changes were made to the experiment room that do not appear in the virtual replica. First, a black tablecloth was laid on the table to reduce the amount of light bouncing off its surface. Second, half of the walls of the room made of glass were covered with blinds. Making these changes and switching to the Oculus Rift CV1 from the HTC Vive, which uses infrared tracking, helped to increase the tracking performance.

To test food interaction in VR, the researcher had to figure out an appropriate food that is easy to acquire and store. Also, food that can be consumed safely and easily with the use of fingers or hands or with a utensil while wearing an HMD. Foods such as biscuits and cookies are easy to get and easy to store but challenging to represent in VR as most people do not eat these foods in one bite. Computer vision can be used to address this issue, but it is another layer of technology that can affect the performance of the system (i.e., tracking). Besides, these foods are not normally eaten with utensils. Marshmallows, on the other hand, is easy to acquire, store and consume. Moreover, they come in different sizes. They are normally eaten with bare hands and can only be eaten using skewers (e.g., kebabs). In this study, the skewers used were made from wood and about 8cm long while the marshmallows were around an inch long and three-quarters of an inch radius. It was white in color and flavored with vanilla. The virtual skewer and virtual marshmallow mesh were created by the researcher.

4.6 Procedure

At the beginning of the experiment, participants were given the opportunity to carefully read the information sheet and consent form. Participants were instructed to:

- Keep their chair within the boundaries set on the floor.

[20] https://www.oculus.com/rift/#oui-csl-rift-games=robo-recall
[21] https://www.ultraleap.com/product/leap-motion-controller/

- Try and keep their hands situated in front of their face or the HMD to ensure good hand tracking. If in any case the virtual hands do not look quite right, they were asked to place their palms facing the headset and allow the Leap Motion Controller to re-calibrate itself.
- Only use their chosen dominant hand for any interaction. The non-dominant hand could remain anywhere on the table and in front of the headset.
- Eat the marshmallows in one bite.
- Place the marshmallows only in the bowl or into their mouths.
- Refrain from moving the bowl. However, they were allowed to touch it or use it as a guide while inside the virtual environment.

Participants were also encouraged to ask questions whenever necessary. If they agreed to participate in the study, they were asked to complete and sign the consent form and afterward complete a demographics questionnaire. They were also informed that the session may take 30 to 40 minutes. Next, participants were asked to use the provided hand sanitizer then proceed with the training task. In the training task, the different hand types and food interactions were explained further. Bare-handed interaction was simple and quite self-explanatory, whereas, in with-utensil interaction, participants had to hold a skewer in a specific way (see Figure 11g). During this training task, they were asked to take one marshmallow and eat it using only their dominant hand, and another one using a skewer. Both tasks were performed directly without wearing an HMD. When participants were ready, they were asked to put on the HMD and start with the first condition.

In each condition, participants had to eat three marshmallows, one at a time at their own pace. Since it is difficult to precisely track individual marshmallows within a bowl, the "Wizard of Oz" technique (Dahlbäck et al., 1993) was used to support this. To make this work, a monitor behind the participant displayed the participant's view of the virtual room that the experimenter used as a guide for when to attach or detach a marshmallow. For AB, participants were presented with articulated hands and were told to pick up the marshmallows with their fingers, while for AU, they were asked to hold the skewer in a certain way (see Figure 11g). For SB, they were presented with a static hand pose (see Figure 11c) to pick up marshmallows from the bowl, while SU provided a static hand pose with a skewer attached to it (see Figure 11d). When a participant took a marshmallow from the bowl, the experimenter pushed a button on a keyboard to attach the marshmallow to a specific mount point on the Leap Motion's hand skeleton. After attaching the marshmallow, the virtual hands were hidden, so the participants would only see a virtual "floating marshmallow" (see Figure 11f) that moved with the hidden virtual hands. This was adapted from a technique known as "Tomato Presence" from a popular VR game called "Job Simulator" (Owlchemy Labs, 2016). Once they put the marshmallow into their mouths, the experimenter, again, pushed a button to bring back the virtual hands.

After each task, participants completed the SUS and IPQ for measuring the sense of presence in a virtual environment. After all four conditions, they were asked to rank (from 1 to 4; 1 being the best) the conditions according to their preference and explain why they ranked them that way.

4.7 Results

SPSS 25 for Windows was used for data analysis. The alpha level for statistical significance was set to 0.05 and to 0.1 for marginal significance. Calculated SUS and IPQ scores were treated with 2x2 repeated measures ANOVA, testing within-subjects effects and pairwise comparisons using Bonferroni adjustment. Preference ratings were analyzed with a related-samples, non-parametric test.

4.7.1 System Usability Scale

From historical data an average accepted calculated SUS score of 68 is considered acceptable (Brooke, 2013). Only AB (*M*[22] = 29.41, SD = 6.107) reached beyond this threshold at 73.542 out of 100 (see Figure 12) which ranks it in the 68% percentile. The other scores ranked based on historical SUS data were as follows: SU (M = 26.62, SD = 7.198) in the 44% percentile, SB (M = 24.95, SD = 7.624) in the 34% percentile, and AU (M = 25.25, SD = 8.497) in the 36% percentile. This suggests below average usability for these conditions.

Results showed marginal significant differences between the SUS scores of the two types of hand fidelity, ($F(1, 23) = 3.707$, $p = 0.067$). There was a significant interaction between the effects of hand fidelity and food interaction on SUS scores ($F(1, 23) = 7.868$, $p = 0.010$). Simple main effects analysis showed that for bare-hand interaction, articulated hands led to higher SUS scores than static hands ($F(1, 23) = 10.430$, $p = 0.004$) while for utensil

[22] All the means in this section are "raw SUS scores" ranging from 0 to 40. "Calculated SUS scores", on the other hand, were obtained by multiplying raw SUS scores by 2.5. These scores range from 0 to 100.

interaction, the type of hand fidelity had no effect ($F(1, 23) = 1.228$, $p = 0.279$). For articulated hands, bare-hand interaction led to higher SUS scores than utensil interaction ($F(1, 23) = 6.461$, $p = 0.018$) while for static hands, the type of food interaction had no effect ($F(1, 23) = 2.647$, $p = 0.117$).

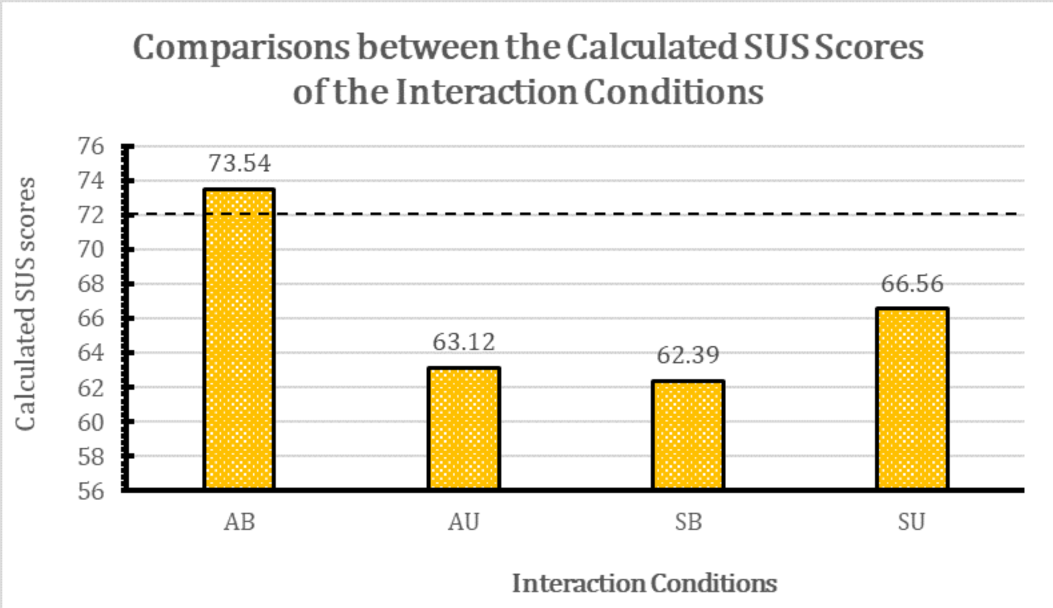

Figure 12: Calculated SUS Scores (0 to 100) with a threshold set at 68.

4.7.2 Igroup Presence Questionnaire

The IPQ has one general item (General Presence, or GP) and three other subscales - Spatial Presence (SP), Involvement (INV) and Realism (RL). See Table 2 for the summary of means and standard deviations and Figure 13 for the comparison of means.

Table 2: Summary of means and standard deviations of IPQ scores

IPQ Subscales	**Food Interaction**							
	AB		**AU**		**SB**		**SU**	
	M	SD	M	SD	M	SD	M	SD
GP	4.75	1.310	3.91	1.640	2.95	1.805	3.45	1.444
SP	4.11	1.155	3.44	1.499	2.77	1.625	3.04	1.276
INV	3.46	1.402	3.17	1.506	2.90	1.461	2.96	1.221
RL	2.71	1.189	2.36	1.118	1.72	1.341	2.15	1.083

GP - General Presence, SP - Spatial Presence, INV - Involvement, RL - Realism

4.7.2.1 General Presence (GP)

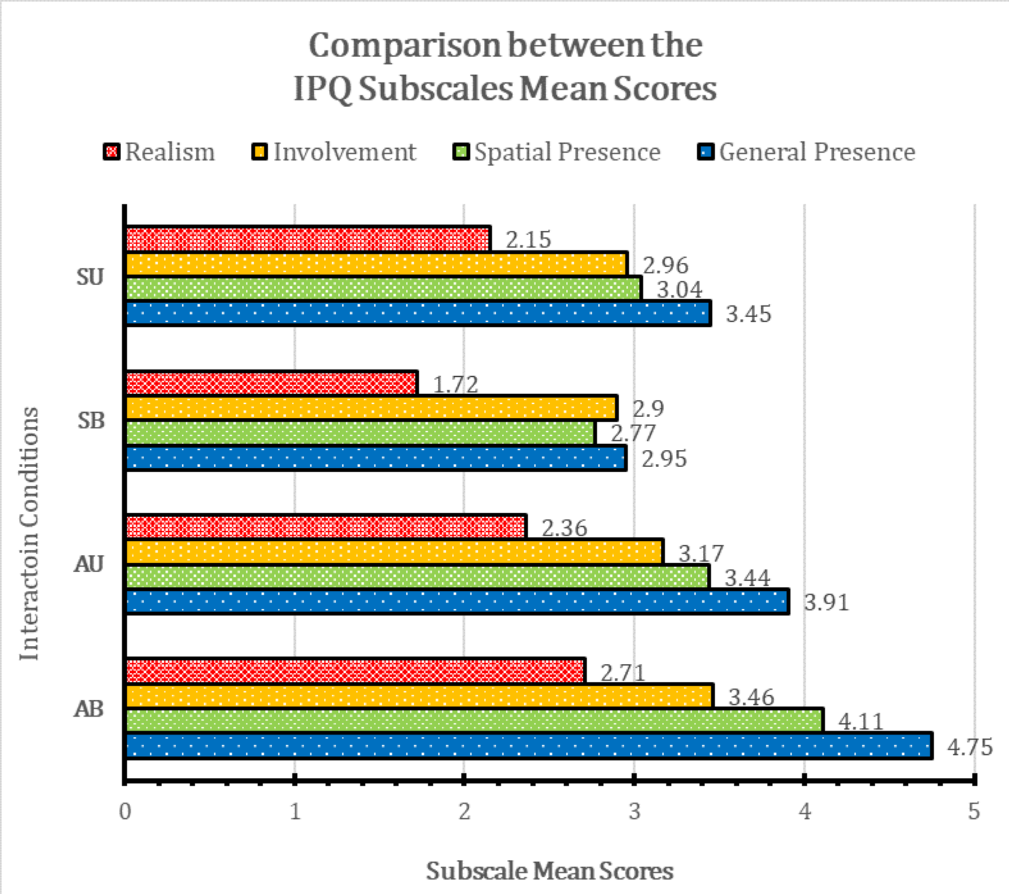

Figure 13: IPQ Subscales Mean Scores

The results showed strong significant difference between the GP scores of the two types of hand fidelity (F (1, 23) = 33.873, p < 0.001) while the types of food interaction did not show a significant difference (F (1, 23) = 0.836, p = 0.370). Pairwise comparison showed that articulated hands scored significantly higher than static hands (p < 0.001). Furthermore, a significant interaction effect was also present between hand fidelity and food interaction (F (1, 23) = 6.400, p < 0.019). Simple main effects analysis showed that for bare-hand interaction, articulated hands led to higher GP scores than static hands (F (1, 23) = 24.625, p < 0.001) while for utensil interaction, the type of hand fidelity had no effect (F (1, 23) = 2.523, p = 0.126). For articulated hands, bare-hand interaction led to higher GP scores than utensil interaction (F (1, 23) = 5.227, p = 0.032) while for static hands, the type of food interaction had a marginal effect (F (1, 23) = 3.450, p = 0.076).

4.7.2.2 Spatial Presence (SP)

There was a strong significant difference between the SP scores of the two types of hand fidelity (F (1, 23) = 19.371, p < 0.001) while the types of food interaction did not (F (1,

23) = 2.488, $p = 0.128$). Pairwise comparison showed that articulated hands scored significantly higher than static hands ($p < 0.001$). Results also showed a marginally significant interaction effect between articulated and static hands ($F(1, 23) = 4.089$, $p = 0.055$). Simple main effects analysis showed that for bare-hand interaction, articulated hands led to higher SP scores than static hands ($F(1, 23) = 18.306$, $p < 0.001$) while for utensil interaction, the type of hand fidelity had no effect ($F(1, 23) = 1.810$, $p = 0.192$). For articulated hands, bare-hand interaction led to higher SP scores than utensil interaction ($F(1, 23) = 4.708$, $p = 0.041$) while for static hands, the type of food interaction had no effect ($F(1, 23) = 1.574$, $p = 0.222$).

4.7.2.3 Involvement (INV)

Results showed no significant differences in the INV scores between the types of hand fidelity ($F(1, 23) = 2.518$, $p = 0.126$) and types of food interaction ($F(1, 23) = 0.983$, $p = 0.332$) and no interaction effects between these two ($F(1, 23) = 0.926$, $p = 0.346$).

4.7.2.4 Realism (RL)

There was a significant difference between the RL scores of the two types of hand fidelity ($F(1, 23) = 15.197$, $p < 0.001$) while the types of food interaction did not, ($F(1, 23) = 0.102$, $p = 0.752$). Pairwise comparison showed that articulated hands scored significantly higher than static hands ($p = 0.001$) An interaction effect was also present between the hand fidelities and food interactions ($F(1, 23) = 5.600$, $p = 0.027$). Simple main effects analysis showed that for bare-hand interaction, articulated hands led to higher RL scores than static hands ($F(1, 23) = 18.134$, $p < 0.001$) while utensil interaction, the type of hand fidelity had no effect ($F(1, 23) = 0.910$, $p = 0.350$). For articulated hands, the type of food interaction had no effect on RL scores ($F(1, 23) = 1.931$, $p = 0.178$) while for static hands, utensil interaction led to higher RL scores than bare-hand interaction ($F(1, 23) = 11.762$, $p = 0.002$).

4.7.2.5 *Preference Rating*

Comparison of the preferences was performed using Friedman's test showing the four conditions were rated differently, $Q\ (2) = 27.450$, $p < 0.001$. Post-hoc analysis with a Wilcoxon signed-rank test indicated that there was a significant difference between AB ($M = 1.38$) and AU ($M = 2.50, Z = -3.298, p < 0.001$), while SB ($M = 3.00$) and SU ($M = 3.13$) showed no significant difference ($Z = -0.296, p = 0.809$). AB was also significantly higher ranked than SB ($Z = -3.912$, $p < 0.001$). There was no significant difference between AU and SU ($Z = -1.702$, $p = 0.902$). Figure 14 shows the mean preference ranks for all four conditions.

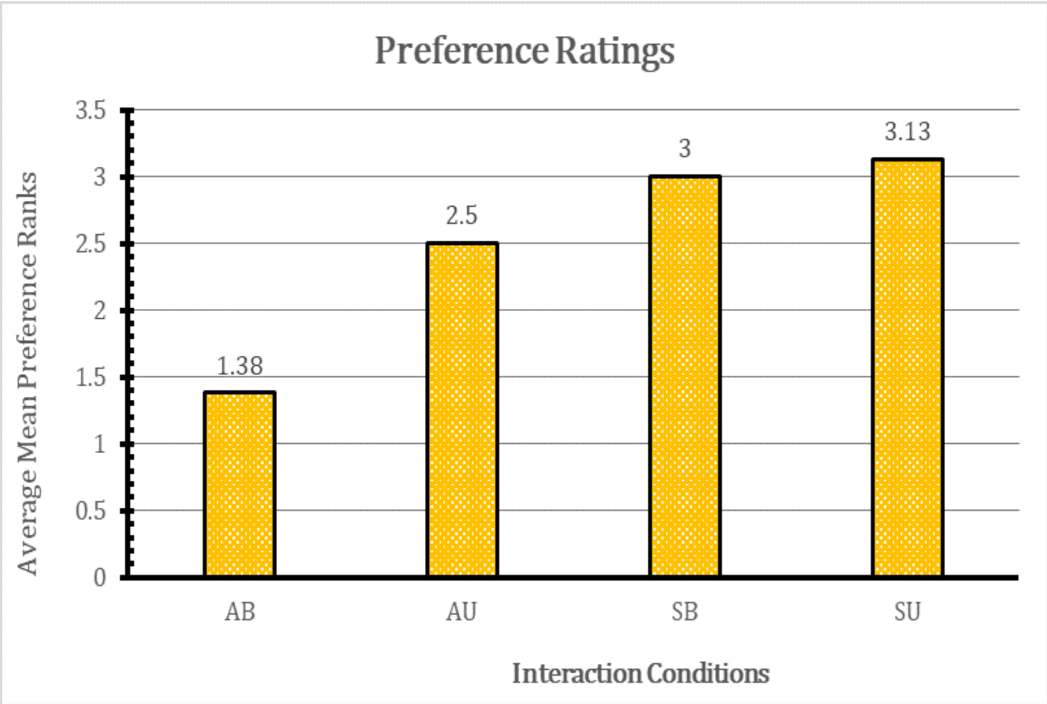

Figure 14: Preference Rating (lower is better)

4.7.3 Summary of Comments

A thematic analysis was also performed on the explanations provided by the participants on their preferences. Most participants said that AB felt more natural, realistic and easy to use. They liked how they could see their fingers move in VR, which made them comfortable using it. For example, some of them mentioned:

"It was easier to pick up marshmallows with articulated hands because I could see where my fingers were."

"...the articulated hands also made the VR world seem more realistic..."

"The articulated hands were more real, and I felt there was better proprioception..."

"It felt more real and interactive with articulated hands..."

"...articulated hands were good and you could grab the marshmallows easy..."

Several participants indicated that AU was somewhat good and realistic, but difficult to work with and could be quite distracting, due to the fact it was harder for them to pick up marshmallows from the bowl with the skewers (similar comments were also mentioned with SU) and their VR hands did not feel like they matched their hands in the real world. Many participants felt that SB and SU were quite simple and easy to use but were not realistic enough. However, in terms of usability with the skewers, some thought that SU worked better than AU. One participant commented:

"The articulated hands also made the VR world seem more realistic. However, when using the skewers, I actually found it easier to have static hands as it could just show me if I was at the bowl and then I could find the marshmallow myself."

4.8 Discussion

Overall, the results and data analysis seemed to partially support some of the hypotheses. In terms of usability, articulated hands and bare-hand interaction was evidently the preferred choice as it almost mimicked the natural movements of our hands and fingers and provided tactile feedback when picking up marshmallows from the bowl, making it more realistic and easier to use. In terms of sense of presence, articulated hands seemed to perform very well compared to static hands but not for the INV scale. Thus, partially supporting the first hypothesis for this study – articulated hands perform better than static hands. On another note, none of the results support the second hypothesis since bare-hand interaction does not seem to be any different from utensil interaction in terms of usability and sense of presence. Bare-hand interaction scored higher in terms of usability and sense of presence when paired with articulated hands which supports the third hypothesis where the type of food interaction would not significantly be different from each other when paired with articulated hands. On the one hand, utensil interaction paired with static hands did not score any higher than bare-hand interaction except for the RL scale which partially supports the hypothesis where utensil interaction with static hands would score higher in terms of usability and sense of presence.

This is an interesting finding. The type of food interaction had no effect on the articulated hands in terms of realism but for static hands, utensil interaction made an effect. This highlights the importance of designing utensils suitable for VR. It is also worth taking note that marshmallows are not commonly eaten with utensils from a bowl (not unless they are on a stick or a cocktail skewer). These results could have been different if the chosen food for the experiment was something like yogurt, which is normally eaten with a spoon and in a bowl. The current utensils that we use in the real world may not necessarily be effective and convenient in the virtual world.

In utensil eating (AU and SU), there was little tactile feedback, considering the marshmallows were not heavy enough to add noticeable weight to the skewer when picked up. The participants only got visual feedback when a marshmallow appeared on their skewer. Between these two, the latter had a higher usability score. Also, even though AU was more limited by the capabilities for the tracking system which sometimes resulted in jittery and inconsistency with the movement of the fingers, this did not seem to affect participants' presence ratings for this condition.

Some participants doing either AU or SU also showed some intriguing behaviors that may have been related to spatial presence or proprioceptive cues. This behavior occurred when a participant held the skewer with the marshmallow near their mouth to eat. Instead of going straight to their mouth, their movement went to their left cheek. Only after realizing it was their cheek that they were feeding did they move to their mouth. There could be several reasons why this happened:

- The position of the HMD on the participant’s head may not have been centered on their face.
- The positions of the virtual hands and skewers may have been different from the participant’s real hands, considering how Leap Motion hands do not scale up or down based on the size of the real hands.
- The visual cues were superior to the proprioceptive cues (Blanchard et al., 2013) .

This study has showed that with the added layer of technology, in this case VR, it made eating a bit more difficult. The participant is unable to see the real food so they significantly on the provided virtual visual cues to feed themselves. This aligns with the food-technology design considerations by Mueller et. al. (2020). Also, it was quite difficult to know how a participant would pick up a marshmallow, so it was challenging to know how exactly to display the virtual marshmallow and the amount of time needed for each task varied from person to person, depending on their eating speed. It is possible that eating interactions may also change depending of the type of food. Evidently, there is a lot more to learn about eating interactions in VR.

5 Conclusions and Future Work

5.1 Development of Food Cravings in VR

In the first study, olfactory and interaction cues were found to increase food cravings. This finding is quite similar to the study of Li and Bailenson (2018) although they measured satiation while in this thesis, food cravings were measured. In their study, they suggest that adding haptic or olfactory cues to a virtual food is enough to invoke satiation while having both cues present does not invoke greater satiation levels. These results complement the first user study's results. The results of the first study show that this increase in the development of food cravings is a good indication that we can have similar eating experiences in VR to those of the real world. This also reminds us that eating is a multisensory experience. Providing or adding different sensory cues in a virtual eating scenario could show us some interesting results. However, this could also potentially mean that we might need to add layers of technology to make this work which can in turn make virtual eating complicated. Moreover, stimulation with both olfactory and interaction cues simultaneously produced no further increase in food cravings. This can be explained by the fundamental attribution error as discussed in section 3.8. This led to the exploration of possible food interactions in VR.

5.2 Food Interactions in VR

The second user study presented a method on how one can feed himself with real food while being immersed in a virtual world compared to previous similar studies who required another person to feed the user (Arnold, 2017; Mehta et al., 2018). This study also looked at the two common ways in which we eat - with our hands and with utensils. The second study showed that bare-hand interactions with marshmallows in VR performed quite well compared to interaction where a utensil was involved. However, further research should examine if similar outcomes will be derived from utensil interactions with other foods. Apart from that, it is also possible that our real-world utensils are just not appropriate for virtual experiences, thus, opening another opportunity for researchers to design exclusive utensils for virtual dining experiences.

A suitable tracking system for the food would have probably helped in terms of tracking accuracy. Currently, there are retro-reflective "edible markers" made of candy (Sato et al., 2019) and agar (Nomura & Oku, 2019), a type of seaweed. These markers seem to be promising, but are still in the early stages of development and may present additional technical challenges such as occlusion, size of the marker, etc. This approach could possibly only work for large enough tangible foods (e.g. cupcakes, pastries) and not for foods that requires to be served in a dinnerware.

5.3 Future Work and Considerations

Aside from technical challenges, we may also face issues that may concern food handling and safety. An example here would be an experience in the second study. To avoid any complications with allergies, participants were screened and only included those who did not have food allergies. Unfortunately, in one of the sessions, a participant showed allergic reactions. Much to the horror of the experiment who saw how red rashes formed around her mouth after a minute or two of taking a bite from the marshmallow during the training phase. This was although the participant reported to have eaten marshmallows as a child.

The field of HFI, particularly in the VR setting, is relatively young. Definite design practices have to be set within the community to make this research exploration effective, as mentioned by Harley et al. (Harley et al., 2018). When it comes to food and eating, there are a lot of technical challenges that still have to be overcome before compelling eating experiences in the virtual world can be created. The following points are some examples:

- What are the standard health and safety precautions that we need to consider? What type of food handling should we do?
- What standard measurements are appropriate for studies such as this research?
- How can we effectively incorporate different olfactory cues/flavor in our systems?
- How do we effectively interact with virtual and real food at the same time? What type of tracking should we use/develop? Haptic gloves might provide better hand tracking but at the cost of hygiene. Can we come up with standard food interactions for finger foods (e.g., cookies, donuts) and non-finger foods (e.g., porridge, yogurt)?
- Are the utensils we use for eating in the real world effective in the virtual world? Do we need to design new utensils for virtual dining?
- How do we effectively track different types of food? Is there a need to create food-grade markers? Is it necessary to track every single aspect of a real food into the virtual or can we get away by providing relevant cues?

- Lastly, with all of previous questions considered, how do we integrate all these in one fluid system? Do we want to attach everything to the HMD? Would it be a comfortable and enjoyable experience? Will users accept such systems? In what situations could such systems best be used?

As we answer these questions, the researcher predicts that more questions and challenges will arise along the way. Although it may seem to be too far into the future to create any useable and marketable VR eating experience, the researcher am excited for that day when we can easily “co-dine” with people all over the world (Wei et al., 2011). Imagine sharing meals virtually with families who may be living overseas or experience different cuisines all around the world without having to physically go to another country. Eating is so ingrained in our daily activities that it deserves to be studied and incorporated for virtual worlds.

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7 Appendix

7.1 Appendix A

This section includes documents related to Chapter 3:

- Ethics approval
- Information sheet
- Consent form
- Recruitment flyer or poster
- Demographic questions
- Pre and post-task questionnaires

Ethics Approval

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Rebecca Robinson
Telephone: +64 03 369 4588, Extn 94588
Email: human-ethics@canterbury.ac.nz

Ref: HEC 2017/44/LR-PS

13 September 2017

Nikita Mae B. Tuanquin
HIT Lab NZ
UNIVERSITY OF CANTERBURY

Dear Nikita

Thank you for submitting your low risk application to the Human Ethics Committee for the research proposal titled "A Feasibility Study on Food Cravings Using Immersive Virtual Eating".

I am pleased to advise that this application has been reviewed and approved.

Please note that this approval is subject to the incorporation of the amendments you have provided in your emails of 23rd August and 4th September 2017.

With best wishes for your project.

Yours sincerely

pp. R. Robinson

Associate Professor Jane Maidment
Chair, Human Ethics Committee

University of Canterbury Private Bag 4800, Christchurch 8140, New Zealand. www.canterbury.ac.nz

F E S

Information Sheet

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Human Interface Technology Laboratory (HIT Lab NZ)
Telephone: +64 3 369 2446
Email: info@hitlabnz.org
2 August 2017

A Feasibility Study on Food Cravings using Immersive Virtual Eating Information Sheet

The principal researcher of this study is Nikita Mae B. Tuanquin, a PhD student at the HIT Lab NZ. The goal of this study is to investigate the effects of olfactory (smell) cues and active participation in the virtual environment on the development of food cravings.

If you choose to take part in this study, your involvement in this project will be to complete a set tasks. You will be briefed on the protocols of the study. Before each task, you will be instructed to take three (3) pre-weighed cotton dental rolls from the provided dispenser and then place each roll in the specified areas of your mouth (one under the tongue and the other two in between of your lower gum and cheeks on both sides). After each task, you will be asked to remove the rolls from your mouth for weighing and to answer the FCQ-S and VAS questionnaires then to a glass of water. Each exposure task will last for two (2) minutes. In between each task, you will be given a five (5) minute break which includes the filling in of the questionnaires and drinking of water. In Virtual Reality (VR) exposure tasks, you will be instructed to wear the HTC Vive headset and to stretch your hands forward for the Leap Motion controller to work. All in all, the whole experiment session will approximately last for 30-45 minutes.

Each session will have five (5) tasks as listed below:
- Be exposed to real chocolate cookies
- Be exposed to chocolate cookies in a photograph
- Be exposed to virtual chocolate cookies in VR
- Be exposed to interactive virtual chocolate cookies in VR with chocolate scent
- Be exposed to a video

In the performance of the tasks and application of the procedures there are risks of nausea which is quite common with users of VR. If at any point you show or feel symptoms of nausea, then you will be asked to stop the experiment for few minutes. There will be couches situated just outside of the experiment room, if needed. If you feel you can no longer resume with the experiment, then you will be free to pull out from it. Also, the researcher will advise you not to drive in the next few hours for you safety. Lastly, there might be a risk of triggering your food allergies, although, the researcher already made sure through a phone screening, that you do not have any food allergies. In case, you did not know you were allergic to the food we were requiring you to eat and you have shown distress during the experiment, the researcher may ask you to withdraw the experiment and contact the UC Medical Centre.

Participation is voluntary and you have the right to withdraw at any stage without penalty. You may ask for your raw data to be returned to you or destroyed at any point. If you withdraw, I will remove information relating to you. However, once analysis of raw data starts on the 10th of September 2017, it will become increasingly difficult to remove the influence of your data on the results.

The results of the project may be published, but you may be assured of the complete confidentiality of data gathered in this investigation: your identity will not be made public without your prior consent. To ensure anonymity and confidentiality, the researcher will not be gathering any personal information from their

Nikita Mae B. Tuanquin

participants except demographic data such as age and gender and experiences in regards with the study. All raw data will be stored in to an encrypted password-protected database. Consent forms will be stored separately in a safe. All these information will be stored at the HIT Lab NZ. Lastly, a thesis is a public document and will be available through the UC Library.

Please indicate to the researcher on the consent form if you would like to receive a copy of the summary of results of the project.

The project is being carried out as a part of a PhD research by Nikita Mae B. Tuanquin (nikita.tuanquin@pg.canterbury.ac.nz) under the supervision of Prof. Robert W. Lindeman (gogo@hitlabnz.org), Dr. Carl Petersen (carl.petersen@canterbury.ac.nz) and Dr. Simon Hoermann (simon.hoermann@canterbury.ac.nz). They will be pleased to discuss any concerns you may have about participation in the project.

This project has been reviewed and approved by the University of Canterbury Educational Research Human Ethics Committee, and participants should address any complaints to The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

If you agree to participate in the study, you are asked to complete the consent form and return it to the principal researcher.

Nikita Mae B. Tuanquin

Consent Form

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Human Interface Technology Laboratory (HIT Lab NZ)
Telephone: +64 3 369-2226
Email: info@hitlabnz.org

A Feasibility Study on Immersive Virtual Eating
Consent Form

Include a statement regarding each of the following:

- ☐ I have been given a full explanation of this project and have had the opportunity to ask questions.
- ☐ I understand what is required of me if I agree to take part in the research.
- ☐ I understand that participation is voluntary and I may withdraw at any time without penalty. Withdrawal of participation will also include the withdrawal of any information I have provided should this remain practically achievable.
- ☐ I understand that any information or opinions I provide will be kept confidential to the researcher, supervisors and other people who will request and be given authorized access to these records. Any published or reported results will not identify the participants. I understand that a thesis is a public document and will be available through the UC Library.
- ☐ I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after ten years.
- ☐ I understand the risks associated with taking part and how they will be managed.
- ☐ I understand that I can contact the researcher, Nikita Mae B. Tuanquin_ (nikita.tuanquin@pg.canterbury.ac.nz) or supervisor/s, Prof. Robert W. Lindeman (gogo@hitlabnz.org), Dr. Carl Petersen (carl.petersen@canterbury.ac.nz) and Dr. Simon Hoermann (simon.hoermann@canterbury.ac.nz), for further information. If I have any complaints, I can contact the Chair of the University of Canterbury Educational Research Human Ethics Committee, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz)
- ☐ I would like a summary of the results of the project.
- ☐ By signing below, I agree to participate in this research project.

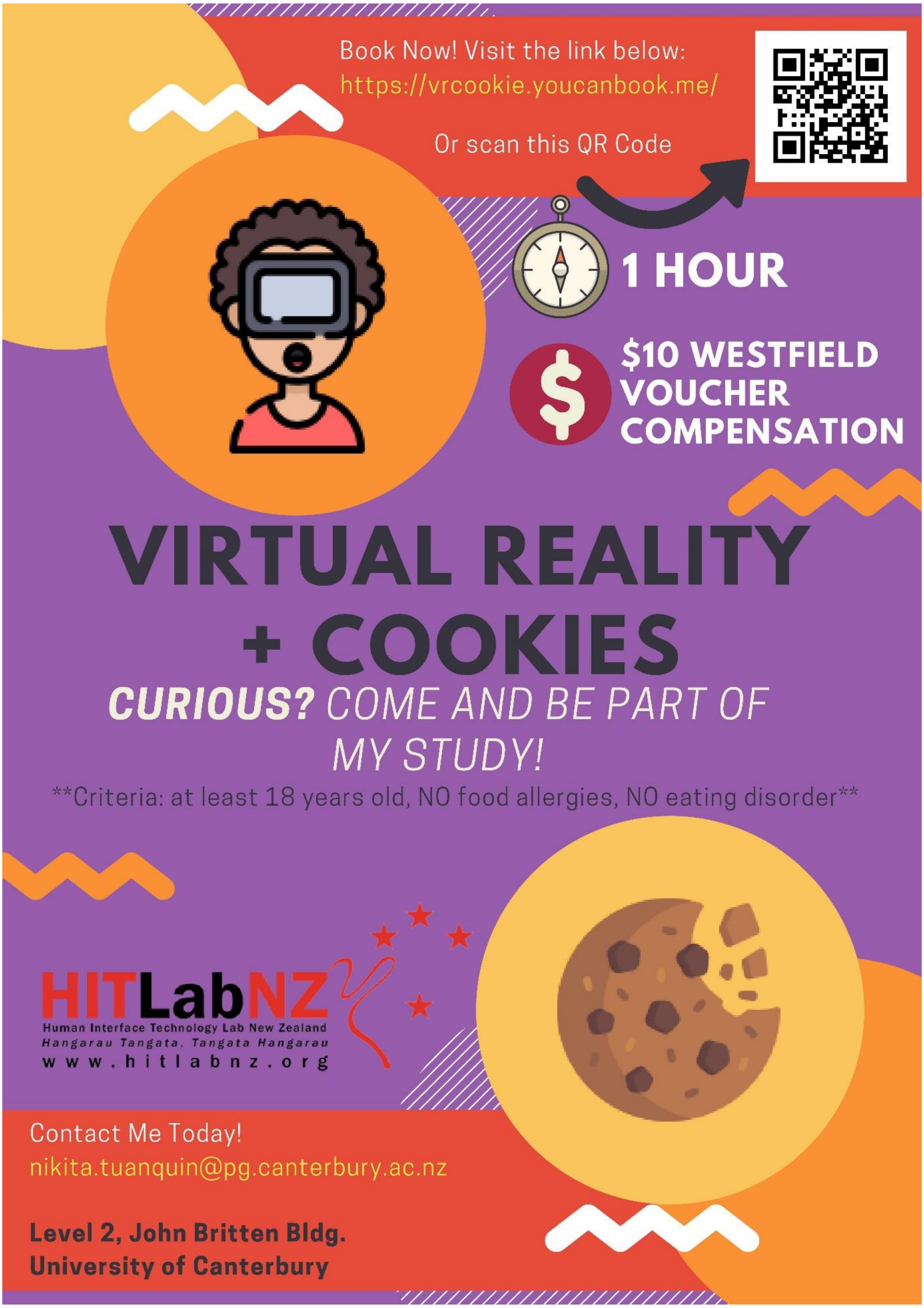
Name:____________________________Signed:__________________________Date:________________

Email address *(for report of findings, if applicable)*:____

Please return this consent form to the principal researcher.

Nikita Mae B. Tuanquin

Recruitment Flyer or Poster



Demographics questions

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CHRISTCHURCH NEW ZEALAND

Development of Food Cravings in Virtual Reality

What is your age?

- ◯ 12-17 years old
- ◯ 18-24 years old
- ◯ 25-34 years old
- ◯ 35-44 years old
- ◯ 45-54 years old
- ◯ 55-64 years old
- ◯ 65-74 years old
- ◯ 75 years or older

What is your gender?

- ◯ Male
- ◯ Female
- ◯ Other

Choose one or more ethnic backgrounds that you consider yourself to be:

- ☐ New Zealand European
- ☐ Māori
- ☐ Samoan
- ☐ Cook Island Maori
- ☐ Tongan
- ☐ Niuean
- ☐ Chinese
- ☐ Indian
- ☐ Other ________

What is your height(cm)?

____

What is your weight(kg)?

____

Pre-task questionnaire

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CHRISTCHURCH NEW ZEALAND

Development of Food Cravings in Virtual Reality

When did you have your last meal?

- ◯ More than 2 hours ago
- ◯ An hour ago
- ◯ Less than half an hour ago

Do you smoke?

- ◯ Yes
- ◯ No

When was the last time you smoked?

- ◯ More than 2 hours ago
- ◯ An hour ago
- ◯ Less than half an hour ago

Did you consume any caffeinated beverages (e.g. coffee, tea, soda) today?

- ◯ Yes
- ◯ No

When was the last time you had a caffeinated drink?

- ◯ More than 2 hours ago
- ◯ An hour ago
- ◯ Less than half an hour ago

Did you chew gum recently?

- ◯ Yes
- ◯ No

When was the last time you chewed gum?

- ◯ More than 2 hours ago
- ◯ An hour ago
- ◯ Less than half an hour ago

Are you currently on medication?

- ◯ Yes
- ◯ No

Do you have any experience with VR?

- ◯ Yes
- ◯ No

Do you like chocolate cookies?

Not at all										Extremely
0	10	20	30	40	50	60	70	80	90	100

Do you like chocolate cookies?

Post-task questionnaire

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CHRISTCHURCH NEW ZEALAND

Development of Food Cravings in Virtual Reality

Did you experience an intense urge or desire to eat the cookie?

Not at all										Extremely
0	10	20	30	40	50	60	70	80	90	100

Did you have a strong urge to eat the cookie?

Please rate how much you agree with the following statements
(1 - Strongly Disagree; 5 - Strongly Agree)

	Strongly Disagree 1	2	Neutral 3	4	Strongly Agree 5
I have an intense desire to eat one or more specific foods	○	○	○	○	○
I am craving one or more specific foods	○	○	○	○	○
I have an urge for one or more specific foods	○	○	○	○	○
Eating one or more specific foods would make things seem just perfect	○	○	○	○	○
If I were to eat what I am craving, I am sure my mood would improve	○	○	○	○	○
Eating one or more specific foods would feel wonderful	○	○	○	○	○
If I ate something I wouldn't feel so sluggish and lethargic	○	○	○	○	○
Satisfying my craving would make me feel less grouchy and irritable	○	○	○	○	○
I would feel more alert if I could satisfy my craving	○	○	○	○	○
If I had one or more specific foods, I could not stop eating	○	○	○	○	○
My desire to eat [one or more specific foods] seems overpowering	○	○	○	○	○
I know I'm going to keep on thinking about one or more specific foods until I actually have it	○	○	○	○	○
I am hungry	○	○	○	○	○
If I ate right now, my stomach wouldn't feel as empty	○	○	○	○	○
I feel weak because of not eating	○	○	○	○	○

7.2 <u>Appendix B</u>

This section includes documents related to Chapter 4:

- Ethics approval
- Information sheet
- Consent form
- Recruitment flyer or poster
- Demographic questions
- Pre and post-task questionnaires

Ethics approval

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Rebecca Robinson
Telephone: +64 03 369 4588, Extn 94588
Email: human-ethics@canterbury.ac.nz

Ref: HEC 2018/11/LR-PS

10 April 2018

Nikita Mae B. Tuanquin
HIT Lab NZ
UNIVERSITY OF CANTERBURY

Dear Nikita

Thank you for submitting your low risk application to the Human Ethics Committee for the research proposal titled "Usability Study: Eating in Virtual Reality (VR)".

I am pleased to advise that this application has been reviewed and approved.

Please note that this approval is subject to the incorporation of the amendments you have provided in your email of 28th March 2018.

With best wishes for your project.

Yours sincerely

pp. R. Robinson

Professor Jane Maidment
Chair, Human Ethics Committee

University of Canterbury Private Bag 4800, Christchurch 8140, New Zealand. **www.canterbury.ac.nz**

F E S

Information Sheet

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Human Interface Technology Laboratory (HIT Lab NZ)
Telephone: +64 3 369 2446
Email: info@hitlabnz.org
June 2018

Usability Study: Eating in Virtual Reality
Information Sheet

Overview

The principal researcher of this study is Nikita Mae B. Tuanquin, a PhD candidate at the HIT Lab NZ. The goal of this study is to investigate how participants interact and eat food while immersed in Virtual Reality (VR). If you choose to take part in this study, your involvement in this project will be to complete a set of steps and tasks.

Step 1:
You will be briefed on the protocols of the study and you need to sign the consent form before you start.

Step 2:
You will answer a background questionnaire including demographic questions and experiences with VR and video games.

Step 3:
Make sure your hands are clean by using the provided hand sanitizer.

Step 4:
Do the pre-test task. This task serves as your "training" task once you're in VR. You will eat 1 marshmallow using only your hands and 1 marshmallow using the skewers. In addition to that, you will also be briefed about the rules of each task. To give you an overview, these are the rules:

- Keep your chair within the boundaries on the floor.
- Once inside VR, make sure your hands are always in front of you.
- Use only your dominant hand when picking a marshmallow from the bowl. Your non-dominant hand should stay on top of the table.
- You must eat the marshmallow in one go.
- You can touch the bowl but do not move it at any cost.
- Do not put marshmallows anywhere except the bowl and your mouth.

Step 5:
You will be asked to start with the tasks. First, you will need to wear the Oculus Rift (VR headset). On the headset there is a camera attached which will track your hands in VR; hence, you need to keep your hands in front of you. Then you will proceed with the set of tasks below:

- Eat 3 marshmallows (one at a time) from the bowl using articulated (animated) hands.
- Eat 3 marshmallows from the bowl using static hands.
- Eat 3 marshmallows from the bowl using articulated hands with skewers.
- Eat 3 marshmallows from the bowl using static hands with skewers.

Each task is around 2-3 minutes. After each task, you will be asked to remove the headset and answer a post-task questionnaire. You have 5 minutes to complete this survey. You may also drink some water during this 5-minute break, if you wish. The whole study session will take about 30-40 minutes. At the end of the experiment, a $10 Westfield voucher will be provided to you.

Nikita Mae B. Tuanquin

Risks
In the performance of the tasks and application of the procedures there are risks of nausea which is quite common with users of VR. If at any point you show or feel symptoms of nausea, then you should remove the headset at any time. There are couches situated just outside of the experiment room, if you need to take some rest. If you feel like you can no longer resume with the experiment, then you will be free to pull out from it. Also, the researcher will advise you not to drive in the next few hours for your safety. In case, you did not know that marshmallow is going to trigger some allergic reactions and you have shown distress during the experiment, the researcher may ask you to withdraw from the experiment and contact the UC Medical Centre.

Data Withdrawal & Privacy
Participation is voluntary and you have the right to withdraw at any stage without penalty. You may askfor your raw data to be returned to you or destroyed at any point. If you withdraw, the researcher will removeinformation relating to you. However, once analysis of raw data starts on the 20th of June 2018, itwill become increasingly difficult to remove the influence of your data on theresults.

The results of the project may be published, but you may be assured of the complete confidentiality of data gathered in this investigation: your identity will not be made public without your prior consent. Toensure anonymity and confidentiality, the researcher will not be gathering any personal information from their participants except demographic data such as age and gender and experiences in regards with the study. Instead, you will be assigned with an alpha-numeric code (e.g. BACD_03) on data sheets to protect confidentiality. Any subsequent access to these data sheets will be to these coded and unidentified data that will not identify you. All raw data will be stored in to an encrypted password-protected database. Consent forms will be stored separately in a safe. All these information will be stored at the HIT Lab NZ. Lastly, a thesis is a public document and will be available through the UC Library.

Please indicate to the researcher on the consent form if you would like to receive a copy of the summary of results of the project.

The project is being carried out as a part of a PhD research by Nikita Mae B. Tuanquin (nikita.tuanquin@pg.canterbury.ac.nz) under the supervision of Prof. Robert W. Lindeman (gogo@hitlabnz.org), Dr. Carl Petersen (carl.petersen@canterbury.ac.nz) and Dr. Simon Hoermann (simon.hoermann@canterbury.ac.nz). They will be pleased to discuss any concerns you may have about participationin the project.

This project has been reviewed and approved by the University of Canterbury Educational Research Human Ethics Committee, and participants should address any complaints to The Chair, Educational Research Human Ethics Committee, University of Canterbury, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz).

If you agree to participate in the study, you are asked to complete the consent form and returnit to the principal researcher.

Nikita Mae B. Tuanquin

Consent Form

Human Interface Technology Laboratory (HIT Lab NZ)
Telephone: +64 3 369-2226
Email: info@hitlabnz.org

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Usability Study: Eating in Virtual Reality (VR)
Consent Form

Include a statement regarding each of the following:

☐ I have been given a full explanation of this project and have had the opportunity to ask questions.

☐ I understand what is required of me if I agree to take part in the research.

☐ I understand that participation is voluntary and I may withdraw at any time without penalty. Withdrawal of participation will also include the withdrawal of any information I have provided should this remain practically achievable.

☐ I understand that any information or opinions I provide will be kept confidential to the researcher, supervisors and other researchers/collaborators in the same research area who will request and be given authorized access to these records. Any published or reported results will not identify the participants. I understand that a thesis is a public document and will be available through the UC Library.

☐ I understand that all data collected for the study will be kept in locked and secure facilities and/or in password protected electronic form and will be destroyed after ten years.

☐ I understand the risks associated with taking part and how they will be managed.

☐ I understand that I can contact the researcher, Nikita Mae B. Tuanquin (nikita.tuanquin@pg.canterbury.ac.nz) or supervisor/s, Prof. Robert W. Lindeman (gogo@hitlabnz.org), Dr. Carl Petersen (carl.petersen@canterbury.ac.nz) and Dr. Simon Hoermann (simon.hoermann@canterbury.ac.nz), for further information. If I have any complaints, I can contact the Chair of the University of Canterbury Educational Research Human Ethics Committee, Private Bag 4800, Christchurch (human-ethics@canterbury.ac.nz)

☐ I would like a summary of the results of the project.

☐ By signing below, I agree to participate in this research project.

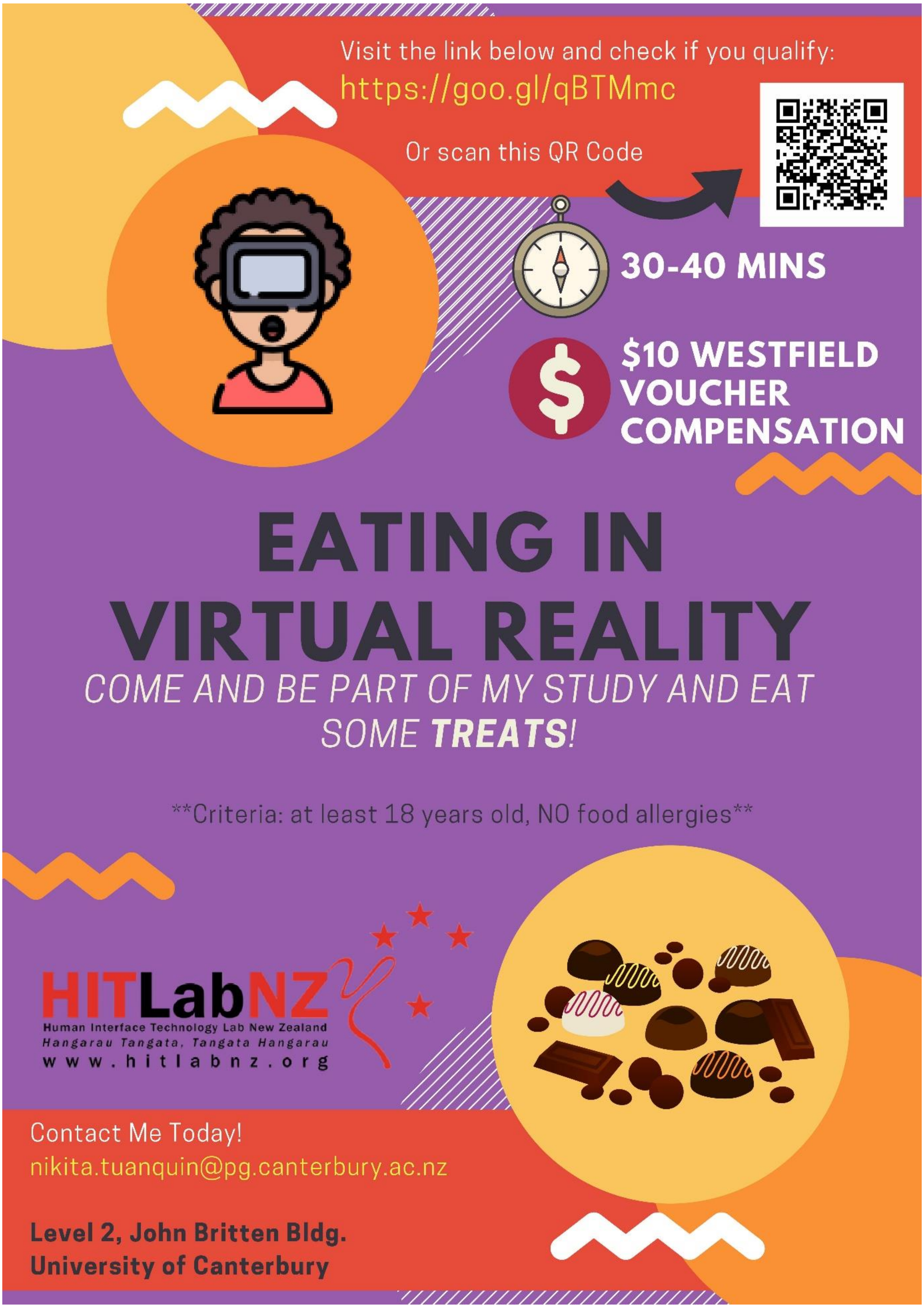
Name:____________________________ Signed:__________________________ Date:________________

Email address *(for report of findings, if applicable)*:____

Please return this consent form to the principal researcher.

Nikita Mae B. Tuanquin

Recruitment Flyer or Poster



Demographic and Pre-task questions

UC
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Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Eating in Virtual Reality

What is your age?

- ○ 18-24 years old
- ○ 25-34 years old
- ○ 35-44 years old
- ○ 45-54 years old
- ○ 55-64 years old
- ○ 65-74 years old
- ○ 75 years or older

What is your gender?

- ○ Male
- ○ Female
- ○ Other

Choose one or more ethnic backgrounds that you consider yourself to be:

- ☐ New Zealand European
- ☐ Māori
- ☐ Samoan
- ☐ Cook Island Maori
- ☐ Tongan
- ☐ Niuean
- ☐ Chinese
- ☐ Indian
- ☐ Other ____________

Do you play video games?

- ○ Yes
- ○ No

Do you have any experience with VR?

- ○ Yes
- ○ No

Which is your dominant hand?

- ○ Left hand
- ○ Right hand

Post-Task questionnaire (IPQ and SUS)

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Please indicate, whether or not each statement applies to your experience. You can use the whole range of answers. There are no right or wrong answers; only your opinion counts.

You will notice that some questions are very similar to each other. This is necessary for statistical reasons.

Please answer all question with reference to the VR session you just completed.

In the computer generated world, I had a sense of "being there".

not at all | ○ ○ ○ ○ ○ ○ ○ | very much

Somehow I felt that the virtual world surrounded me.

fully disagree | ○ ○ ○ ○ ○ ○ ○ | fully agree

I felt like I was just perceiving pictures.

fully disagree | ○ ○ ○ ○ ○ ○ ○ | fully agree

I did not feel present in the virtual space.

did not feel present | ○ ○ ○ ○ ○ ○ ○ | felt present

I had a sense of acting in the virtual space, rather than operating something from outside.

fully disagree | ○ ○ ○ ○ ○ ○ ○ | fully agree

I felt present in the virtual space.

fully disagree | ○ ○ ○ ○ ○ ○ ○ | fully agree

How aware were you of the real world surrounding while navigating in the virtual world? (i.e., sounds, room temperature, other people, etc.)?

extremely aware | ○ ○ ○ ○ ○ ○ ○ | not aware at all

I was not aware of my real environment.

fully disagree | ○ ○ ○ ○ ○ ○ ○ | fully agree

I still paid attention to the real environment.

fully disagree | ○ ○ ○ ○ ○ ○ ○ | fully agree

I was completely captivated by the virtual world.

fully disagree | ○ ○ ○ ○ ○ ○ ○ | fully agree

How real did the virtual world seem to you?

completely real | ○ ○ ○ ○ ○ ○ ○ | not real at all

How much did your experience in the virtual environment seem consistent with your real world experience ?

not consistent | ○ ○ ○ ○ ○ ○ ○ | very consistent

How real did the virtual world seem to you?

about as real as an imagined world | ○ ○ ○ ○ ○ ○ ○ | indistinguishable from the real world

The virtual world seemed more realistic than the real world.

fully disagree | ○ ○ ○ ○ ○ ○ ○ | fully agree

I think that I would like to use this system frequently.

Strongly Disagree | ○ ○ ○ ○ ○ | Strongly Agree

I found the system unnecessarily complex.

Strongly Disagree | ○ ○ ○ ○ ○ | Strongly Agree

I thought the system was easy to use.

Strongly Disagree | ○ ○ ○ ○ ○ | Strongly Agree

I think that I would need the support of a technical person to be able to use this system.

Strongly Disagree | ○ ○ ○ ○ ○ | Strongly Agree

I found the various functions in this system were well integrated.

Strongly Disagree | ○ ○ ○ ○ ○ | Strongly Agree

I thought there was too much inconsistency in this system.

Strongly Disagree | ○ ○ ○ ○ ○ | Strongly Agree

I would imagine that most people would learn to use this system very quickly.

Strongly Disagree | ○ ○ ○ ○ ○ | Strongly Agree

I found the system very cumbersome to use.

Strongly Disagree | ○ ○ ○ ○ ○ | Strongly Agree

I felt very confident using the system.

Strongly Disagree | ○ ○ ○ ○ ○ | Strongly Agree

I needed to learn a lot of things before I could get going with this system.

Strongly Disagree | ○ ○ ○ ○ ○ | Strongly Agree

Post-Task questionnaire (Preference Rating)

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You're almost there! Now, rank the interaction that you liked the best (1 - Best)

- Eating marshmallows with articulated hands
- Eating marshmallows with articulated hands and skewer
- Eating marshmallows with static hands
- Eating marshmallows with static hands and skewer

From the previous question, can you explain why you ranked those items in that order?

Which interaction between these two (articulated hands vs. static hands) did you prefer?

○ Articulated hands

○ Static hands

Which interaction between these two (articulated hands and skewer vs. static hands and skewer) did you prefer

○ Articulated hands and skewer

○ Static hands and skewer

Even with the VR headset on, can you still see a bit of the real world (especially near the nose)?

○ Yes

○ No